HANDEDNESS AND LIFE EXPECTANCY: DO ONLY THE GOOD DIE YOUNG?

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ABSTRACT

This thesis examines the topic of left-handedness and details the problems research has had in advancing knowledge in this area, due to equivocal and contradictory research. Limitations of the current research in the field are discussed, particularly the practice of dichotomising subjects into two handedness groups when evidence suggests that handedness may be multi-dimensional.The latest controversy concerning left-handedness is also examined. This is Coren and Halpern's (1991) claim that left-handers are more likely to die at a younger age than right-handers. The explanations and studies supporting this claim are examined, and an archival study similar to Halpern and Coren (1988) is reported. Halpern and Coren (1988) compared the mean age at death of 1472 right-handed and 236 left-handed American baseballers, finding a significant difference in the mean age at death of left- and right-handers using a Wald-Wolfowitz Runs test (Siegal, 1956). However they failed to take into account the large time span over which subjects were born, and thus the need to consider year of birth cohorts. The present study used 1861 right-handed and 204 left-handed first-class English cricketers. When the data were examined using birth cohorts, an advantage in terms of mean age at death was found for right-handers born before the late 1800's. However since then the mean age at death of right- and left-handers appears similar. It is concluded that whether or not a difference is found between the mean age at death of left- and right-handers will depend on the proportions in the sample born before or after the late 1800's. Directions for future research are also outlined and the need to escape from a myth of laterality is suggested.

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CHAPTER ONE

INTRODUCTION

For reasons that are not yet adequately understood, the majority of humans use their right hand to perform unilateral tasks such as writing and throwing while a minority use their left hand. This preference for the left by some people has evoked much interest as well as many negative attitudes towards left-handers (Harris, 1980).

While many left-handers are capable of rising to the top in their chosen fields (e.g., Leonardo Da Vinci, Michaelangelo), an examination of the psychological literature finds that many studies positively correlate left-handedness with detrimental conditions and problems (Harris, 1980). The negative findings concerning left-handers appear to have culminated in the finding by Coren and Halpern (1991) that left-handers are more likely to die at a younger age.

The aim of this thesis is to conduct a study similar to one, Coren and Halpern used as evidence for their claim that left-handedness is a marker for decreased survival fitness. The literature will also be reviewed to examine the reasons why psychologists would consider it plausible for left-handers to die at a younger age. Before this though, just what is meant by left-handedness?

1.1 WHAT IS LEFT-HANDEDNESS AND HOW IS IT MEASURED?

Many people have pondered the questions 'why are people left-handed?' and 'are left-handers different to right-handers?' without much success. Perhaps part of the problem and the reason for so much conflicting research on handedness is that the more basic question of 'what is left-handedness?' has not yet been satisfactorily resolved (Perelle, Ehrman & Manowitz, 1981; Satz, Achenbach & Fennell, 1967). Obviously, if researchers have different conceptions as to what constitutes handedness, they are unlikely to agree on its causation and possible correlates.

Central to the problem of what is left-handedness is how handedness is assessed. This is because what is left- and right-handedness appears to be very much a function of how handedness is measured and what a researcher's criteria are (Steingrueber, 1975). Many different methods have been used to assess handedness. These include performance measures which compare the speed, strength and dexterity of the two hands on particular tasks and a variety of preference measures which ascertain which hand a person prefers to use when undertaking a task. The methods for assessing hand preference include:

1. Self-report: - Asking a person if they are left- or right-handed.
2. Familial reporting:- Asking the handedness of family members. For instance when people are asked the handedness of their parents or other relatives.
3. Writing hand: - The hand used for writing is taken as the preferred hand.
4. Observation: - Subjects are observed performing different tasks and the hand that is used is noted.
5. Questionnaire: - This involves presenting subjects with a number of tasks in the form of a questionnaire and asking which hand is preferred. The number of items in handedness questionnaires varies greatly, as does the choices given to answer the questions. For instance some tests may give a person a choice of answering only left or right, while others may give a trichotomy of left, right, both/either. Still others use a continuum from strongly right handed, through to strongly left handed with more moderate responses in between (Beaton, 1985).

Each of these methods has its disadvantages for assessing hand preference. For example one, would assume that a self-report would be accurate because a person should know if they are left- or right-handed. However Satz, et al. (1967) found that only half of the self-classified left-handers in their study used the left hand for more than seven out of ten preference activities and 14% of them actually did more activities with the right hand. Coren (1992) describes a subject in one study who reported that he was right-handed. However when tested on a variety of tasks it was found that he used his left hand for all of them except writing.

Asking people the handedness of their family members also appears suspect, because offspring under-report their parent's left-handedness. In one study, high school students were asked about their parent's handedness and the reports were then checked against questionnaires sent directly to the parents. Whereas the students described 4.1% of their parents as left-handed, the parents themselves reported a 9.1% incidence of sinistrality (Porac & Coren, 1979). Self-report is also not a useful procedure for using with young children who may not be aware of their hand preference, or are not yet able to differentiate between left and right.

The hand used for writing in literate cultures is the most obvious example of a task where one hand in particular is used and it is one that is often used to classify people as either right- or left-handed. However there are problems with this method of classification because in the past, and in some countries (e.g., Taiwan) there are strong social pressures exerted against writing and eating with the left hand (Corballis, 1983). Hence, assessing a person's handedness by using their writing hand as the criterion may well underestimate the number of people in a population with left-handed tendencies.

Actual observation of a person's hand preferences would appear to be a more effective way of determining handedness. However this procedure can be very time consuming when large number of subjects are involved. For this reason questionnaires have been the most popular method used to assess handedness (Coren & Porac, 1978).

1.1.1 Questionnaires

Many different questionnaires have been used in the study of handedness. Some researchers create their own while others use the more well known questionnaires, either in their original form, or modified in some way. Examples of popular questionnaires include those by Crovitz and Zener (1962), Annett (1967), Oldfield (1971) and Steenhuis and Bryden (1989). These questionnaires ask people to state the hand they prefer to use when performing everyday activities.

Questions that are common to all of these inventories refer to writing, throwing, hammering, using scissors, holding a needle, using a toothbrush and using a tennis racket. Other items frequently found in questionnaires of this type include drawing, dealing cards, using a knife, using a match and the hand used to hold the top of a broom when sweeping.

Even though there are several items in common between the questionnaires, different scoring methods are used. Crovitz & Zener (1962) and Steenhuis & Bryden (1989) (the Waterloo Questionnaire) give subjects a choice on a five point scale of always or mostly using the preferred hand, or being able to use either hand. This results in a score ranging between 14 and 70 for the Crovitz and Zener scale or between -120 and +120 for the Waterloo Questionnaire. The result is a measure of the direction (left or right) and strength (strong or weak) of a person's hand preference.

Annett's (1967) questionnaire gives subjects the choice of saying they prefer the left or the right hand or can use either. Annett also distinguishes between primary and secondary questions within her inventory. Primary questions were found by association analysis to be highly correlated with each other, while secondary questions were not as highly rated and were regarded as less important. Depending on subjects answers to the questionnaire, they were divided into eight groups, including consistent and inconsistent left- and right-handers and other groups in between, such as left and right ambidexters.

Oldfield's Edinburgh Handedness Inventory (1971) is often used in handedness research (Williams, 1991). In this questionnaire, subjects are instructed to indicate the strength of their hand preference for each of the ten items by putting one or two ticks in the left or right column or one tick in each column if they are indifferent about that item. A subject's score is measured in terms of a laterality quotient which is the number of ticks in the left column subtracted from the ticks in the right column divided by the total number. This results in a score (the laterality quotient) which can range from -100 (totally left-handed) to +100 (totally right-handed).

The use of the laterality quotient has not gone uncriticised. The reason is that there is more than one way that a particular score can arise. For instance it is possible for a subject to get an LQ of +100 by putting between 10 and 20 ticks in the right column so long as there are no ticks in the left-hand column (McMeekan & Lishman, 1975; Williams, 1991). It is not known whether a subject putting 10 ticks is as strongly right-handed one who puts 20 ticks. McFarland and Anderson (1980) also found that the laterality quotient was influenced by variation arising from sources other than handedness, such as age, and questioned its validity.

In an attempt to overcome the problems with the laterality quotient and to enable an analysis of the factor structure to be undertaken, some researchers using the EHI (e.g., Bryden, 1977; McFarland & Anderson, 1980; White & Ashton, 1976) have used a one to five graded response. However there has been little research as to the effect that this different scoring method has on the results obtained using the EHI.

1.1.2 Problems with questionnaires

Questionnaires are a popular and convenient method where the intention is to relate handedness to the prevalence of certain diseases and disorders. However the use of questionnaires in handedness research has been criticised by a number of authors (e.g., Barnsley & Rabinovitch, 1970; Salmaso & Longoni, 1985) and it has been suggested that the conflicting results found by handedness researchers may in part be due to the use of questionnaires in place of more definitive indices, in the assessment of handedness (Beaton, 1985).

One of the major objections to the use of questionnaires is that the number and type of questions, the scoring methods, and the classification of subjects into handedness groups are purely arbitrary (Beaton, 1985; Peters & Murphy, 1992; Salmaso & Longoni, 1985). The reason for this is that a clear grasp of what handedness is has not yet been attained. In fact, as will be shown, the same people can be assessed as having different handedness according to the type of questionnaire used.

The lack of a theoretical basis for determining how hand preference should be assessed means that there is little agreement amongst researchers as to what criteria should be used to select items for use in questionnaires, or even how many items should be included. While short inventories of 10 to 15 items are convenient, there is debate as to whether this type of questionnaire is the best to use. Bryden (1977) suggests shortening the EHI to the six items which load best on the general handedness factor isolated by factor analyses, while other authors have suggested that the use of writing hand alone will provide nearly as much information as a questionnaire (Annett, 1976; Plato, Fox & Garruto, 1984; Williams, 1991). However still others (e.g., Chapman & Chapman, 1987; Salmaso & Longoni, 1985) insist that writing hand does not provide an accurate assessment of handedness.

At the other extreme Provins, Milner and Kerr (1982) argue that shorter questionnaires give a false impression of consistency and longer questionnaires are needed to give a comprehensive coverage of hand preference. Steenhuis and Bryden (1989) and Healey, Liederman & Geschwind (1986) also advocate the use of longer questionnaires.

A further example of the arbitrariness of handedness questionnaires is shown when inventories supposedly measuring the same construct of handedness are compared. It would be hoped that if two questionnaires were measuring the same phenomena then those subjects who were classified as strongly left- or right-handed on one questionnaire would obtain the same rating on the other scale. This does not appear to be the case. McMeekan & Lishman (1975) compared the Annett Hand Preference questionnaire and the Edinburgh Handedness Inventory and found that of the subjects who scored the maximum left handed score on the EHI (LQ -100), 21% were not classified as consistent left-handers on the Annett questionnaire. Similar figures were found for right-handers.

Peters (1992) has systematically investigated how different questionnaire procedures affect prevalence figures for left-handedness in a given population of subjects. He used five questionnaires (60 items, 31 items, 12 items, eight items and four items). The two longest questionnaires were answered using a graded response from one to five. The other three were answered first using graded responses and then by forced choice where the subjects had to answer either left or right. Each questionnaire was evaluated with four different cut-off criteria for right-handedness. The criteria were set at 100%, 90%, 80% and 50%. For example in the 100% criterion, a subject had to say they used the right hand for all items before they would be classified as right-handed.

The different cut-off criteria, questionnaire lengths, and response modes all had a marked effect on the estimates of left-handedness in the same group of subjects. When the 100% criterion was used, there is a marked difference between the types of questionnaire results because the longer questionnaires produce few people who are considered fully right-handed. However when a 50% criterion is used the effects of questionnaire procedure disappear and all the questionnaires give similar prevalence figures.

These results show that handedness prevalence figures can be very sensitive to questionnaire procedures and cut-off criteria. In the most striking case, with the 100% criterion, the 60 item questionnaire and graded responses, less than 1% of subjects are classified as right-handed! At the other extreme the four item, forced response questionnaire yields more than 80% right-handers.

While the arbitrariness of handedness questionnaires has been criticised, there are also problems with the actual items used in many of the more popular questionnaires. One issue is that in most questionnaires, each item is weighted equally. As Annett (1970) points out, there is no empirical evidence for this equivalence. For instance is it more important for an assessment of handedness if a person writes with their left hand, or unscrews a jar with their left hand?

Annett (1970) has attempted to solve this problem by separating items in her questionnaire into primary and secondary questions with most emphasis on the primary questions. McFarland and Anderson (1980) recommend giving smaller weightings to the items scissors, knife, broom and box lid on the EHI, or excluding them altogether, because they load poorly on a 'handedness factor As yet, no one appears to have taken up the suggestion.

Yet another problem with the assessment of handedness is the relationship between performance and preference measures. It would be reasonable to assume that the hand with the best performance would be the preferred hand but this is not always the case (Provins & Cunliffe, 1972a). Some self-proclaimed right-handed subjects perform certain tasks better with the left hand. Even more left-handed individuals exhibit superior performance with the right hand on measures such as strength and dexterity (Benton, Meyers & Polder, 1962; Provins & Cunliffe, 1972a; Satz et al., 1967).

An example of the effect that different handedness measures can have is given by Connolly and Bishop (1992). They compared the handedness of children from England and Papua New Guinea (PNG). When writing hand was used as the index of handedness, the two groups did not differ in the proportion of left-handers. However the results from a nine-item handedness inventory suggested that PNG children were significantly more right-handed than the English sample, while a measure of manual performance indicated that PNG subjects were less right-handed.

It can be seen that the classification of who is a left-hander depends on the researcher's criteria and these can vary greatly. In addition questionnaire results have shown that there are some tasks, such as turning on a light switch and picking up objects that even strongly left- or right-handed subjects can do equally well with either hand (Beukelaar & Kroonenberg, 1983; Steenhuis & Bryden, 1989). This raises the question as to what tasks are important in the assessment of handedness.

1.2 SKILLED TASKS AS A MEANS TO DETERMINE HANDEDNESS

Several studies using performance measures have concluded that tasks involving higher amounts of skill or complexity (such as writing and manipulating small objects) are the ones that best differentiate between the hands. For tasks that are relatively simple, there is often little or no difference in the performance of the hands. For example, reasonably simple tests of performance such as strength (Bruml, 1972; Lewandowski, Kobus, Church & Van Orden, 1982; Provins & Cunliffe, 1972a; Rigal, 1974) and steadiness (Simon, 1964) fail to accurately differentiate between the hands. If a person is stronger with one hand, this does not enable one to accurately predict that this hand will be the one that is used the most.

Steingrueber (1975) tested subjects' handedness using dotting and tapping on squares tasks, both with three different levels of complexity (size of squares and radius length). He found that fewer people could do the tasks better with their left hand as the tasks became more complex. In other words at a low complexity level there are people who can perform the task well with both hands but as the complexity increases only those who are very skilled with the left hand are able to perform better with this hand.

Provins (1956) also found that the extent of the difference between the two hands was a function of test complexity. A simple task involving flexion of the index finger to produce pressure resulted in no significant difference between the preferred and non-preferred hand. However a more complex aiming task did result in significant differences between the hands. He concluded that when making simple muscle movements, one hand is no better than the other.

The results from these studies appear to be suggesting that there are differences between the hands in performance and the differences may be most noticeable when tasks involve fine, complex movement. Peters (1990a) interprets this as a distinction between tasks that matter and those that do not. For instance it does not matter what hand is used to reach for an apple on a table because there is no cost involved in using the non-preferred hand, both hands are able to do the task. However hand writing is a task that does matter because the writing has to be legible and there is a cost involved in using the less adept non-preferred hand. According to Peters, discussion of handedness should focus on tasks that matter, because they will show the differences between the hands.

While this may seem an obvious conclusion, many handedness questionnaires contain items that people can do with either hand. When a person answers that these tasks could be performed with either hand, the final score shows them to be only weakly left-or right-handed. However a score based on tasks that actually matter would indicate their quite strong lateral preference.

1.3 EXPLANATIONS FOR HAND DIFFERENCES

It is apparent that most people prefer to use one hand over the other for particular tasks and there is also evidence that despite the two hands being structurally identical there are differences between them in their performance (Annett, 1992; Annett, Hudson & Turner, 1974; Todor & Kyprie, 1980). The question now is what mechanisms are involved in causing the performance difference between the two hands? There are a number of areas within the motor system where differences in hand performance could be brought about. For instance it could be in the brain or it may be that the non-preferred hand has muscles or tendons that do not respond as quickly to messages from the brain.

Flowers (1975) is generally regarded as being among the first to examine this topic (Carson, 1989). He differentiated between ballistic and corrective movements. Ballistic movements occur too fast to be modified by feedback (Carlson, 1986). Feedback occurs when the on-going activity of the motor system is corrected using information from the senses and muscle receptors (Reber, 1985). A movement taking less than 300 msec to perform is considered ballistic because there is insufficient time for corrective movements to take place (Flowers, 1975).

In contrast, corrective movements are those where the motor system output is continually adjusted using feedback information. In this type of movement the output is monitored and can be corrected if deviations occur (Flowers, 1975). This type of distinction has received support from other studies (e.g., Todor & Smiley, 1985).

Flowers (1975) used two tasks in his experiment. One was a tapping task where subjects were required to hit two targets alternately with a stylus with the number of hits being scored. It was assumed that this task required each movement to be under current sensory control and involve corrective movements. The second was a rhythmical tapping task where subjects were asked to tap out rhythms repetitively as fast as they could, without aiming the movement to hit any particular point. Performance in this task was ballistic in the sense that relatively little control of the position or force of each tap was necessary and also that it was usually impossible to correct individual errors in the required rhythms within one unit of the sequence.

Flowers found a significant difference between the two hands in the aiming task but not in the rhythmical tapping task. He concluded that the difference in performance between the two hands occurred during corrective rather than ballistic movements. Flowers hypothesized that this difference in motor control was related to the sensorimotor feedback loop where some central processing operation is performed to transmit sensory and feedback information to the motor system. The non-preferred hand may have a lower rate of information transmission on such tasks so that sequential adjustments of ongoing motor activity take slightly longer with the non-preferred hand. According to this theory the differences between the hands is in the time taken to go through the sensorimotor loop and the sequence of operations necessary to maintain continuous control of movements using current sensory and/or feedback information.

Another hypothesis to explain the difference in performance between the hands has been proposed by Annett, Annett, Hudson & Turner (1979) and Peters (1980). By minutely examining the movement involved in performing a finger tapping task, Peters (1980) was able to isolate the particular part of the movement that gave rise to differences in performance between the hands. The 'reversal phase' of the tapping process was found to be the major contributor to hand differences. The reversal phase is the transition phase from the flexor (downward) movement to the extensor (upward) movement. However the time taken for the reversal portion of the tapping movement is too short to allow for direct involvement of sensory feedback in the guidance of reversal. Hence Peters (1980) rejects the idea that the advantage of one hand over the other, is due to a more efficent sensorimotor control loop, as Flowers (1975) suggests.

Instead Peters (1980) argues that differences in the precision of force modulation contribute to the differences in hand performance. Force modulation is the precision with which the activation of interacting muscles are timed and the magnitude of excitatory outflow. It involves the timing and sequencing of motor commands as well as their intensity (Peters & Durding, 1979).

Peters and Durding (1979) found that subjects performing a tapping task with the non-preferred hand reported a 'lack of control' in their hand characterized by a feeling that the movement intent was not as reliably translated into actual movement as it is with the preferred hand. In other words there appeared to be difficulty in controlling (modulating) the force used in the finger tapping. When a more difficult tapping task is used, the non-preferred hands performance suffers because much greater subtlety of force is required.

Annett (1979, 1985) agrees with the proposal of Peters that the superiority of the preferred side is not due to a better capacity to process feedback information but rather to more efficient control of the motor output. Annett et al. (1979) conducted a frame by frame analysis of high speed film recordings of a peg moving task and found that the preferred and non-preferred hands moved at similar speeds and corrected errors (hitting the board in the vicinity of the hole) equally fast. There were no substantial differences between them except that the preferred hand made fewer mistakes. In other words, the preferred hand does not move faster, but it has better aim and hence it is likely to meet the goals set for it more quickly (Annett et al., 1979). This can be interpreted as showing that the motor output of the non-preferred hand is more variable.

Todor and Smiley-Oyen (1987) also examined the factors that contributed to the difference in the rate of tapping between the preferred and non-preferred hand. Consistent with Peters (1980) they found that a hand's superior rate of tapping was attributable to a shorter duration of key depression. The non- preferred hand also had a longer average time between successive force peaks (i.e., key being pushed downwards). Therefore the hand was not only slower in completing the directional reversals but was also typically slower in generating the motor outflow necessary for successive taps. Also in accordance with Peters (1980), this study found that the range of force was greater in the non-preferred hand and it was more variable in both directions. Thus not only did it exert variable amounts of force during key depression but it also varied more in the amount of force applied in an upward direction.

There are two main perspectives then, on why the hands differ in performance. One suggests that the observed asymmetries are a function of reduced variability of motor output for the preferred hand (e.g., Annett et al., 1979) or a function of greater precision of force modulation (e.g., Peters, 1980; Todor & Smiley-Oyen, 1987). The second view emphasises the possible differential efficiency with which feedback information is processed (e.g., Flowers, 1975; Todor & Doane, 1978).

Carson (1989) interprets the results of Roy and Elliott (1986), which examined the relationship between accuracy and speed of hand movement, as showing that both types of processes may be occurring. He suggests that the right hand (he did not consider left-handers) is superior during movement execution because of the enhanced ability of the left hemisphere to concurrently process sensory feedback. This asymmetry reflects both the spatial complexity of the task with which the individual has to deal and a greater variability of the non-preferred hand in modulating force output. As Peters (1989) points out though, differences in force modulation between the hands are an outcome not a cause of the difference in modulation. There is as yet no adequate explanation of what is the cause of the differences in force modulation.

While some progress has been made in this area there are still many questions to be answered. For instance, performance studies have concentrated on a small number of unimanual tasks such as finger tapping and peg moving. Other tasks involving different facets of movement remain to be explored. Also many tasks involve hand-eye co-ordination and as yet it has not been established if there is a differential relationship between the eyes and the preferred and non-preferred hand.

To summarise then, the essence of handedness appears to be skill in fine, complex movements rather than broader actions. The superiority of the preferred hand for this type of movement may be due to the better control over movement it has or faster feedback from the brain. As yet the precise mechanisms that contribute to one hand being able to perform actions better than the other have not been discovered, probably because the production of finger and hand movements is a complex process and there is still a lot that is not known about it. Research in this area is still trying to determine why the right hand is better than the left and the question of why some people have a better left hand has not yet been adequately addressed.

1.4 SEPARATE DIMENSIONS OF HANDEDNESS

As the previous section has shown, there are hypotheses emerging to try and explain why one hand is better at performing tasks than the other. This research has been based mainly on performance studies of handedness. Support for the need to distinguish between skilled and less skilled tasks in handedness research has also come from preference studies.

Steenhuis and Bryden (1989) factor analysed a 60-item questionnaire and found four major factors. One, a general handedness factor, consisted of activities such as writing, throwing a ball and inserting a pin into material. The second included picking up objects such as books and a glass of water. The third factor comprised items that involved picking up heavy objects such as suitcases. Both the second and third factors were characterised by less lateralized responses, meaning that people did not have as strong a hand preference as they did for factor one items. The fourth factor related to the use of bats and axes.

Steenhuis and Bryden (1989) proposed that the major difference between the factors is that factor one is made up of tasks consisting of 'skilled' unimanual motor activity, while factors two and three contain less skilled tasks which have weaker hand preferences because either hand can do them. The authors suggest that the fundamental feature of a skilled task is that it entails a relatively complex sequence of motor behaviours such as those involved in writing, using tweezers and hand sewing. These tasks invoke a strong preference for using a particular hand. In contrast the tasks that load onto factors two and three are less skilled and have weaker hand preferences.

Liederman and Healey (1986) also found results comparable to Steenhuis and Bryden (1989), with their subjects having a distinct hand preference for one factor but not for another. Beukelaar and Kroonenberg (1983) found that there were a number of tasks a sizeable minority of right-handers (8-16%) performed with the left hand. These tasks included opening a lid, rumpling paper and using a rake, broom and spade which Steenhuis and Bryden (1989) would characterise as low skilled tasks.

Findings such as these are interesting because they suggest that handedness may be multi-dimensional. Many factor analytic studies have been conducted using short questionnaires such as the EHI and have found one general handedness factor (Brito, Brito, Paumgartten & Lins, 1989; McFarland & Anderson, 1980; Williams, 1986). This has been interpreted as proof that handedness is a unitary phenomenon. However there are now suggestions that this is not the case.

Palmer (1964, 1974) suggested that there may be a distinction between hand movements involving gross arm - shoulder musculature and those that entail precision control in hand movements. Factor analytic studies on large questionnaires have indeed found that there may be different dimensions to handedness. For example, two handed tasks such as using an axe or bat have been found to be a separate factor (Plato et al., 1984; Steenhuis & Bryden, 1989; Steenhuis, Bryden, Schwartz & Lawson, 1990).

There is also evidence to suggest that there is a separate factor relating to hand strength (Dean, 1982; Steenhuis & Bryden, 1989). This is not surprising given that hand strength does not correlate well with other measures of hand performance and preference (Provins & Cunliffe, 1972a, 1972b). The idea that there are different dimensions to handedness also receives support from other performance studies. Fleishman (Fleishman & Hempel, 1954; Fleishman & Ellison, 1962) has shown that there are independent performance dimensions such as speed, dexterity and aiming. It is possible that some people may have one hand that is superior for all these functions but others may have each hand superior for different dimensions.

Suggestions to explain the different dimensions of handedness include the different muscle groups and/or joints that are used to perform the tasks. For instance some involve just finger movement while others involve arm and finger movement (Beukelaar & Kroonenberg, 1983). Healey et al. (1986) suggested a distinction between axial (control of trunk and eye movements) and pyramidal movements (such as those in the fingers) but their findings did not support this separation (Steenhuis & Bryden, 1989).

Further evidence that there may be different dimensions of handedness is the finding of Peters and Servos (1989) and Peters (1990b) that there may be distinct groups of left-handers. They distinguished between consistent and inconsistent left-handers. Consistent left-handers show a marked stability in hand choice and performance favouring the left hand. However inconsistent left-handers appear to show a disassociation between strength and tasks requiring fine manual dexterity. While the majority of this group were superior with the left hand on finger tapping and peg moving tasks, they were stronger with the right hand and also tended to throw with the right hand even though they wrote with the left hand.

To summarise then, not only is it important to focus on 'skilled' tasks to gain an understanding of handedness but it is becoming apparent that there may be different dimensions to handedness. This raises doubts as to the usefulness of discussing left- and right-handedness as though they were unitary phenomena. In theory, a person may be left-handed on one dimension but not another.

The aim of this chapter has been to highlight the problems involved in trying to compare groups of left- and right-handers. It is apparent that the definition of what is a left-hander is arbitrary and to consider left-handedness as a unitary phenomenon may hide important differences between those who use the left hand. The findings outlined in this chapter cast doubt on the appropriateness of the methodology used by Coren and Halpern (1991) which dichotomised subjects into left- and right-handed groups without acknowledging important sub-groups within these.

Although it may not be appropriate to compare groups of left- and right-handers, many studies in the area continue to do this. Chapter Two will focus on some of this research that Coren and Halpern (1991) claim as support for their hypothesis that left-handers are more likely to die at a younger age.

CHAPTER TWO

REASONS WHY LEFT-HANDERS MIGHT DIE YOUNGER

Chapter One has highlighted some of the problems involved in trying to ascertain exactly what is meant by the term 'left-handed' and it is apparent that the deceptively simple question of 'what is a left-hander' has not yet been adequately answered. Nevertheless there are numerous studies that compare left- and right-handers on different variables. To support their claim that left-handers are more likely to die at an earlier age, Coren and Halpern (1991) use some of these studies to provide explanations as to why this should be the case.

If Coren and Halpern (1991) were looking for an explanation as to why left-handers should die at an earlier age, they did not have to look far. The psychological research is full of studies claiming that left-handers are inferior or deficient in some way (Hardyck & Petrinovitch, 1977). If one examines the number of diseases and disorders that left-handedness is supposedly associated with, it would be surprising if left-handers did not die at an earlier age. Coren and Halpern (1991) outlined four reasons in particular to explain their finding that left-handers die at an earlier age than right-handers. These were:

1 Neuropathology resulting from prenatal or perinatal birth stress.
2 Disruptions to the immune system because of in utero exposure to elevated hormonal levels.
3 Immature or irregular physiological development due to disruptions in the normal maturational process.
4 Left-handers being more prone to accidents because they are living in a world designed for right-handers.

Each of these explanations will be examined to see if they can explain Coren and Halpern's (1991) assertion that left-handers die at an earlier age than right-handers.

2.1 LEFT-HANDEDNESS IS ASSOCIATED WITH NEUROPATHOLOGY

Coren and Halpern (1991) suggest that a reason why left-handers may die at an earlier age than right-handers is because left-handedness "is a marker for some form of neurological insult that may in turn reduce survival fitness in the sinistral group" (p. 98). The suggestion that left-handedness may be an indicator of brain damage has been a popular one in psychological research. The two major theories that advocate this hypothesis are the so called one type and two type theories of pathological left-handedness. These two theories and the evidence for them will be discussed to ascertain if they could explain a reduction in the life expectancy of left-handers.

2.1.1 Bakan's one type model of pathological handedness

In 1971 Bakan published a one page article in the journal, Nature. In it he noted that the frequency of left-handedness was greater in males and twins who also had higher rates of birth trauma, which could lead to brain damage. From this he hypothesized that when left-handedness was present it indicated some form of brain damage that resulted from birth stress.

Unfortunately Bakan (1971) chose a rather indirect method of testing this hypothesis. He assumed that since stressful prenatal birth conditions were associated with high risk birth order (first or fourth or later births) then left-handers would be found more often in these groups than in low risk birth orders. Bakan (1971) found a significant difference between the percentage of left-handers in the two birth order groups for males and a non-significant but similar trend for females. This was subsequently replicated by Bakan, Dibb and Reed (1973), although they did not separate subjects according to gender. They suggested that cerebral anoxia (lack of oxygen to the brain prior or during birth) damaged the left hemisphere of the brain and caused the switch to left-handedness.

Bakan (1975) suggested that left-handedness could occur by itself or in association with other conditions such as mental retardation and cerebral palsy and was part of the continuum of reproductive casualty. However he claimed that left-handedness by itself did not imply any intellectual deficit (Bakan, 1977), although this was not apparent from the title of his 1975 article "Are left-handers brain damaged?".

As mentioned previously, using birth order as an indicator of birth stress is indirect to say the least and was probably a major reason for the number of conflicting studies in this area. Several authors failed to replicate Bakan's findings (e.g., Hicks, Evans & Pellegrini, 1978; Leiber & Axelrod, 1981; Nachshon & Denno, 1986; Smart, Jeffery & Richards, 1980) and the major reviews of Harris & Carlson (1988) and Searleman, Porac & Coren (1989) have concluded that there is no relationship between birth order and handedness. However since birth order is an indirect measure of birth stress, the failure to find a relationship between birth order and handedness does not discount the possibility of an association between handedness and more direct measures of birth stress (Searleman et al., 1989).

An improved method of examining the relationship between birth stress and left-handedness is to focus on the birth stressors themselves and compare the rates of subsequent left-handedness between those who did and did not suffer birth complications. A problem with this is that both left-handedness and birth stress are low frequency events. This means that fairly large shifts in lateral preference are needed to achieve statistical significance meaning that smaller but theoretically interesting shifts may not be noticed (Searleman et al., 1989). Despite this, many studies have investigated the relationship between handedness and birth stress using a variety of methods.

One method was to ask students if there had been any complications during their birth (e.g., Bakan et al., 1973; Leiber & Axelrod, 1981). However this is not very accurate because by definition, it is relying on second hand information which could lead to inaccuracies (Searleman et al., 1989; Smart et al., 1980; Schwartz, 1990). Another way of collecting data on birth complications was to ask the mothers of subjects about any stressful events that may have occurred during their child's birth. Unfortunately when one study compared these reports to hospital records, discrepancies were found between them and so maternal reports cannot be regarded as accurate either (Schwartz, 1990).

In two major reviews of the pathological left-handedness literature, which included many studies using these methodologies, neither Harris and Carlson (1988) nor Searleman et al. (1989) found much in the way of evidence to prove that birth stress was related to left-handedness. The meta analysis of Searleman et al. found that when birth stressors were considered individually, they did not correlate very highly with increases in non-right-sidedness but when considered as a group, birth stressors were more likely to be associated with increases in non-right-sidedness than with increases in right sidedness. However all the relationships including the significant ones were very weak and accounted for less than 1% of the variance.

Both reviews pointed out a number of methodological problems with the studies that investigated the relationship between handedness and birth stress; including the number that relied on maternal or subject reports of birth stress. Both Searleman et al. (1989) and Harris & Carlson (1988) suggested that a more stringent method of trying to ascertain the relationship between birth stress and left-handedness was to use hospital records of birth complications.

Schwartz (1990) used this method and obtained both maternal and hospital reports on a wide range of birth stressors and complications for 400 children. Only five significant results were found out of 108 analyses conducted and only two of the five were in the direction predicted by the pathological theory of handedness. Smart et al. (1980) and McManus (1981) also examined hospital records of birth complications and found no relationship between handedness and birth stress. It appears then that when more stringent measures of birth stress and handedness are used, there does not appear to be compelling evidence that all left-handedness is caused by birth stress or complications (Nachshon & Denno, 1987).

Some authors (e.g., Leiber & Axelrod, 1981) suggest that if Bakan's birth stress hypothesis were true and all left-handers were the result of some form of neurological damage, then it would be expected that they would have lower scores on measures of intelligence and attainment than right-handers, (although Bakan, 1977 says this is not necessarily so). There does not appear to be any evidence of left-handers as a group showing a cognitive deficit in comparison with right-handers (Annett & Turner, 1974). In numerous studies based on large populations of subjects, no differences have been found between left- and right-handers in cognitive ability (Hardyck & Petrinovich, 1977). There has been a suggestion that left-handers may score lower than non-right-handers on tests of non-verbal visuospatial ability, but not on verbal intelligence (Levy, 1969). However Bishop (1990), after a review of the literature in this area, concluded that the results were more of an "accumulated series of type one errors" (p. 86) than an actual difference.

It could also be argued that if the brain damage was severe enough to force right-handers to use the left hand, then it should prevent them from using the right hand for skilled tasks. However there are many examples of left-handers who have been taught to use the right hand, especially for writing (Leiber & Axelrod, 1981).

In summary then, Bakan's theory that all left-handedness is the result of brain damage caused by birth or in utero complications has not in general, been supported. The relationship between birth stress and left-handedness is equivocal with the more rigorous studies finding little evidence in favour of the theory. In addition large population studies of the cognitive abilities of left- and right-handers have failed to find the differences expected if left-handers were brain damaged in some way.

While population studies fail to find any differences in the cognitive abilities of left- and right-handers, studies on certain groups with brain damage have found higher rates of non-right-handedness in these groups. This has led to the hypothesis that some but not all left-handedness is caused by brain damage. The major proponent of this theory is Satz (1972) and his two type theory of pathological left-handedness will now be outlined.

2.1.2 Satz's two type model of pathological handedness

Satz (1972) constructed his theory of pathological left-handedness after noting that researchers had reported a raised incidence of left-handedness in a variety of clinical populations including stutterers, epileptics, mental retardates and those with language disorders. His model is based on the postulate that early damage to one cerebral hemisphere can result in the decreased function of the contralateral hand. If that hand is the preferred one then this may cause the person to switch their hand preference and become a pathological left- or right-hander. Since there are many more natural right-handers than left-handers in the population there will be more pathological left-handers than pathological right-handers and they will be a larger proportion of left-handers as a whole (Satz, 1972; 1973).

Satz (1972) suggests the reason for the higher incidence of left-handedness in people with epilepsy and mental retardation is because brain damage is the cause of both the pathological left-handedness and the condition. So while Bakan (1971, 1973) proposes that all left-handedness is pathological, Satz is suggesting that only some left-handedness is pathological and the rest is natural, resulting from genetic or environmental determinants (Satz, 1972).

A problem with Satz's model is it was based on only two handedness groups whereas as Chapter One has shown there may be groups within these broader categories. Soper and Satz (1984) extended the model to incorporate ambiguous handedness because the original model did not account for the high rates of ambiguous handedness (lack of manual preference in either hand and changing hands on the same task) found in autistic subjects. Satz, Orsini, Saslow and Henry (1985) took the idea even further by postulating the existence of a pathological left-handedness syndrome. Symptoms of the syndrome include left-handedness, a marked discrepancy between verbal and performance IQ, shorter right-sided limbs and impaired visuo-spatial performance.

It can be seen that Satz's theory of pathological left-handedness depends on evidence of left-handedness in clinical populations known or assumed to have brain damage. This relationship may sound simple to establish or contradict, but the research investigating the relationship between left-handers and certain disorders has been fraught with disagreement and controversy. While clearcut results are becoming apparent in some areas, other relationships continue to be cited as fact when the results are far from convincing. One reason is that not only do researchers have different definitions of left-handedness, but there is also debate as to how some of the disorders that handedness is correlated with should be defined (e.g., dyslexia) (Bishop, 1990).

As discussed previously, an argument against Bakan's one type theory of pathological left-handedness was that large scale studies found no difference in the cognitive capabilities of left- and right-handers. However Annett and Turner (1974) report findings on cognitive abilities that support Satz's two type model. They conducted vocabulary, drawing and maze tracing tests on left- and right-handed children. When the abilities of the different handedness groups were compared over the total sample, no significant differences were found. However when those at the lower end of the distribution were examined separately, an excess of left-handers was found. The authors interpreted this as support for Satz's (1972) theory since it suggests that a group of pathological left-handers is the cause of the excess of left-handedness at the low end of the distribution while other left-handers are no different to right-handers in terms of ability.

Several disorders and conditions have long been associated with left-handedness. Evidence of a higher than expected rate of left-handedness in these groups would support Satz's claim that some left-handedness is pathological. The evidence for this will now be examined.

Mental Retardation

One conclusion that seems to be agreed upon is that left-handedness is more frequent in mental retardates, possibly as much as double that found in normal populations (Harris & Carlson, 1988; Pipe, 1990). Also, the more severe the mental retardation, the higher the rate of left-handedness (Bradshaw-McAnulty, Hicks & Kinsbourne, 1984).

Epilepsy

In a review of the literature, Harris and Carlson (1988) conclude that there is a higher than average number of left-handers amongst epileptics which could be as much as double the normal rate. It appears that the increase in non-right-handedness in epileptics is due to those who have suffered early damage to the left hemisphere (Satz, 1972).

Autism

As mentioned, Soper and Satz (1984) modified the pathological theory after they found that autistic subjects had high rates of ambiguous handedness. Bishop (1990) also notes that non-right-handedness in autism takes the form of ambiguous handedness and pathological influences do seem to be a factor in some autistic children.

Dyslexia

It has been suggested that dyslexia (when a person's reading ability is very poor relative to their intelligence) is caused by weak or inconsistent cerebral lateralization and that left-handedness is also an indicator of weak lateralization so they may be linked in some way (Zangwill, 1960).

The relationship between left-handedness and dyslexia is encompassed in many theories (e.g., Annett, 1985; Geschwind & Galaburda, 1987) which may explain why many people believe that there is a link between them, although the research is contradictory. Bishop (1990) reviewed the literature in this area using stringent criteria and found that there were no differences in handedness between dyslexic and control children. She also noted that a sample size of nearly 400 would be needed to determine if there was a relationship and very few studies had this. It is possible though, that someone with more favourable views on the relationship between dyslexia and left-handedness would review the same research and obtain a positive conclusion because different criteria may be used to include or exclude certain studies, thereby changing the conclusion.

Speech and Language Disorders

Like the dyslexia research, the debate on whether there is a relationship between left-handedness and speech and language disorders has been marked by a lack of agreement in the literature. It is hypothesised that the brain damage that may cause a person to switch hands may also damage areas of the left hemisphere which are responsible for language functions. Therefore it is predicted that amongst those with speech and language disorders there will be an excess of left-handers (Bishop, 1990).

Harris and Carlson (1988) list studies that both reject and support a relationship between speech and language disorders and handedness. They conclude that the data are so inconsistent that no strong conclusions can be drawn. A link between stuttering and left-handedness or enforced right-handedness is a cherished belief of many, but again there is no consistent evidence on this relationship.

As Bishop (1990) concludes, it appears that there are higher rates of non-right-handedness in groups such as mental retardates, epileptics and autistics which show brain damage. This is not the case however, for developmental disorders where the evidence is contradictory and equivocal. Given this, it appears that as Satz (1972, 1973) suggests, some left-handedness may be pathological and caused by brain damage prior or during birth and it could also be argued that these people will have a shorter than average life expectancy. However it is debatable as to whether this group of left-handers would be enough to account for a reduction in the overall life expectancy of left-handers as a whole especially as much as the nine year difference found by Halpern and Coren (1988).

2.2 DISRUPTION TO THE IMMUNE SYSTEM

Geschwind and Galaburda's (1987) theory of lateralization has prompted a lot of interest and much research into the relationship between handedness and immune disorders. They hypothesized that a foetus exposed to testosterone would exhibit delayed growth of the left hemisphere which would result in modified cerebral lateralization, disrupted early language development and impaired immune functioning due to the thymus gland being affected. This theory therefore predicts that left-handedness will be associated with a higher rate of immune disorders.

Coren and Halpern (1991) suggest that if left-handers are more likely to suffer from immune disorders then they will be at a greater risk from infection and over time their weaker immune system may not be able to protect them as well as it should, leading to an earlier death. This reasoning may appear sound but unfortunately there are several problems with it.

Although Geschwind and Galaburda (1987) do suggest a relationship between left-handedness and immune disorders, they stress that left-handers are only part of a larger group who have anomalous dominance and it is this group as a whole that is more likely to suffer from immune disorders.

According to Geschwind and Galaburda (1987) people with anomalous dominance are those who do not have speech and handedness functions situated in the left hemisphere. They estimate that this group constitutes approximately 30-35% of the population, a much higher proportion than those who are left-handed. This means that there are people who use their right hand who should also be at risk of suffering an earlier demise because of their weak immune system but Coren and Halpern (1991) do not acknowledge this.

Geschwind and Galaburda (1987) also stress that even though they suggest that left-handers may be more likely to have certain medical conditions resulting from a disruption to the immune system, this does not mean that left-handers have an overall disadvantage in terms of disability or death. As they point out, there are many diseases that only females suffer from but females on average still outlive men. They suggest that left-handers (or those with anomalous dominance) will demonstrate low rates of other diseases such as cancer. It is indicative of the attitudes towards left-handedness that this positive hypothesis has been ignored, both by Coren and Halpern (1991) and other researchers in the field.

The previous two arguments against using a weakened immune system as an explanation for the earlier death of left-handers assume that Geschwind and Galaburda's (1987) hypotheses are true. In actual fact this is far from the case. Many attempts have been made to replicate certain findings but often they have not been able to substantiate the claims made by Geschwind and Galaburda (1987). When looking specifically at the relationship between immune disorders and handedness, the research, like so much relating to left-handedness, is contradictory and confusing. However there are enough negative reports (e.g., Bryden, McManus, & Steenhuis, 1991; McKeever & Rich, 1990) to cast doubt on the link.

2.3 IMMATURE PHYSIOLOGICAL DEVELOPMENT DUE TO DISRUPTION OF NORMAL MATURATION PROCESSES

A third hypothesis suggested by Coren and Halpern (1991) is that right-handedness or sidedness is a function of the normal maturation of the nervous system and that if this is disrupted or delayed, it could result in an increase in left-sidedness. They also suggest that the delay could be caused by some factor such as birth stress, which could lead to some form of "physiological irregularity that contributes to reduced survival fitness" (p. 99).

They cite studies showing that left-handers are smaller in terms of size and weight and are later to develop than right-handers as evidence that they are delayed in maturation. However it is a big leap to assume that just because someone is a late developer that they are going to die younger and Coren and Halpern (1991) present no evidence to support this.

Coren and Halpern (1991) also claim support for the maturational lag hypothesis by claiming that people become more right-handed with age. However as will be shown in Chapter Three there is no evidence that this is the case.

2.4 LEFT-HANDERS ARE MORE LIKELY TO HAVE ACCIDENTS

The final explanation for the earlier demise of left-handers offered by Coren and Halpern (1991) pertains to accidents. Since left-handers live in a right biased world with objects such as lathes, band saws and safety switches on industrial machines being designed for right-handers, there is a chance that left-handers will be more likely to have accidents which could in turn lead to an earlier death.

To test this hypothesis, Coren (1989) conducted a survey among 1,896 university students. Subjects were asked to report if, in the previous two years they had had any accidents using tools or implements, driving a vehicle, when at home, at work or participating in sports. Only accidents resulting in injuries that required medical attention were considered. It was found that both male and female left-handers had higher relative risks than right-handers for each category, although this was only statistically significant for injuries obtained when driving a vehicle.

In contrast Peters and Perry (1991) collected data from 302 left-handers and 719 right-handers and found no support for the claim that left-handers have an elevated risk of traffic accidents. In fact they found that female right-handers were more likely to report having an accident than female left-handers and there was no difference between the two groups of males.

Porac (1993) surveyed 486 subjects who had sustained hand injuries and their handedness data was compared to 402 respondents (matched for age and sex) with no experience of hand injury. She found no difference in the number of left-handers in the two groups (8.7% compared to 8.8%) and concluded there was no evidence that left-handers were more likely to have accidents which injure their hands than right-handers.

Salive, Guralnik & Glynn (1993) analyzed data from American census figures. They estimated that the percentage of deaths due to injuries for left-handers would be more than twice that of right-handers but this was because left-handers are a younger aged population than right-handers and younger people have more accidents. Clearly then this area is one where more research is needed before it can be assumed that left-handers are more likely to have accidents.

To summarise, Coren and Halpern (1991) have put forward several suggestions to explain why left-handers would be more likely to die at a younger age than right-handers. While they may seem valid at first glance, a closer examination reveals that each of them has problems. By ignoring evidence that does not agree with their conclusion, Coren and Halpern (1991) have put together what seems like a convincing account for an earlier death of left-handers, but further investigation shows the account to be seriously flawed.

This chapter has outlined some of the justifications Coren and Halpern give for the hypothesis that left-handers are more likely to die at a younger age than right-handers. It can be seen that while much research suggests that left-handedness is associated with particular diseases and disorders, a great deal remains controversial. The evidence for left-handers having higher rates of immune disorders, accidents or immature physiological development is far from concrete. While it is quite likely that a certain proportion of people become left-handed for pathological reasons, which in turn may affect their life expectancy, it is doubtful whether these could account for the large difference in mean age at death found by Coren and Halpern (1991).

This chapter has examined the psychological research and rationale that Coren and Halpern (1991) cite as support for their claim. Chapter Three will look specifically at the Coren and Halpern studies which they claim demonstrate that left-handers die at a younger age.

CHAPTER THREE

COREN AND HALPERN'S EXPLANATIONS FOR LEFT-HANDERS DYING YOUNGER

Coren and Halpern's (1991) hypothesis that left-handedness is a marker for decreased survival fitness (i.e., left-handers die younger) was prompted by the finding that there are smaller proportions of left-handers in older age groups. The studies that have reported this finding will now be outlined.

3.1 EVIDENCE OF LOWER PROPORTIONS OF LEFT-HANDERS IN OLDER AGE GROUPS

Several studies (e.g., Brackenridge, 1981; Coren & Porac, 1979; Spiegler & Yeni-Komshian, 1983) have assessed handedness in terms of writing hand and found that there were greater proportions of left-handers in younger age groups and substantially fewer in older age groups. It could be argued that studies using only hand writing as an indicator of handedness will underestimate the number of left-handers in older age, because many of them will have been forced to use their right hand for writing in their younger years. However even studies that use questionnaires with several items find smaller proportions of left-handers in older age groups (e.g., Tan, 1983).

Fleminger, Dalton and Standage (1977) assessed the handedness of 800 adult psychiatric patients and 800 controls aged between 15 and 64 years, using a 12-item questionnaire. In both groups, the proportion of subjects labelled right-handed increased progressively with increasing age while the proportion of left- and mixed-handers decreased with age. For example, in the control group, 11% of 15-24 year olds were left-handed compared to only 3% in the 55-64 age group.

Plato et al. (1984) tested 705 subjects for handedness and separated them into three age groups; under 40 years, 40-59 years and 60 years and older. In general, there were proportionally fewer left-handers in the older age group, but this varied as a function of the task being measured. For instance, the number of subjects choosing to use a baseball bat left-handed stayed approximately the same over the three age groups. Tambs, Magnus and Berg (1987), Porac, Coren and Duncan (1980), Ellis, Ellis and Marshall (1988) and Lansky, Feinstein and Peterson (1988) report similar findings.

The study of the relationship between handedness and age that Coren and Halpern (1991) base their mortality hypothesis on was conducted by Porac and Coren (1981). It involved collecting data from 5,147 subjects ranging in age from 8-100 years. They found that the proportion of left-handed subjects decreased from around 15% for respondents less than 20 years of age to 5% for those in their 50s, to virtually 0% for respondents over 80.

When subjects were categorised into one group under 45 years and another group over 45, it was found that the age trend was based on both an increase in the number of individuals classified as consistently right sided and a drop from 6% to 2% of those considered left-handed. There was also a decrease in the number of subjects classified as mixed-handed.

However although this study involved a very large number of subjects, only 37 where aged over 75. If the incidence of left-handedness is taken to be approximately 10% then only 3 or 4 left-handers would have been expected from this group and even fewer if any of them had been forced to change hands. Also only 14% of subjects were aged over 45 making it hard to compare groups based on such uneven sample sizes. So while the sample size is large, few were in the critical older age groups.

Porac and Coren (1981) used four items to assess hand preference: throwing, drawing, erasing and dealing cards. Both drawing and erasing are tasks that could be influenced by a teacher or parent and Peters (1990b) has shown that there exists a group of left-handers who use the right hand to throw. The item 'dealing cards' has been found to have good test retest reliability (Liederman & Healey, 1986; Raczkowski, Kalat & Nebes, 1974) but Chapman and Chapman (1987) report that some subjects had difficulty answering this question and both they and Porac, Coren, Steiger & Duncan, (1980) report low correlations between this item and others. This choice of items may have had an effect on the numbers of left-handers being reported.

Although a number of studies have found that there are proportionally more right-handers and fewer left-handers in older age groups, there are studies which have not reported such a trend. For instance Brito et al. (1985, 1989) found a significant effect of age on the handedness of men but not women using the EHI with Brazilian subjects.

Dellatolas et al. (1991) compared the hand preferences of subjects from Algeria, Greece, Italy, France and Spain using a questionnaire. They found a systematic increase with age of strong right-handedness and a decrease in mixed right-handers but there was no systematic decrease in the frequency of left-handedness with age. They concluded that only if a substantial proportion of mixed right-handers were included as left-handers, would a decrease in the proportion of left-handers occur with age.

Kilshaw and Annett (1983) found no evidence of a trend toward increasing right-handedness over the 12-63 age span of their sample. The proportions of consistent right-handers were at least as high in the youngest subjects as in adults and the proportion of those showing a bias to the left hand were stable across age groups. Subjects handedness was assessed using a questionnaire and a performance measure (peg-moving). Ellis et al. (1988) suggest Kilshaw and Annett did not find any age differences because their subjects were students, and that this may have introduced some bias in the results, although they did not suggest how.

3.2 REASONS FOR LOWER PROPORTIONS OF LEFT-HANDERS IN OLDER AGE GROUPS

Despite the studies that do not substantiate the finding of fewer left-handers in older age groups, it is generally accepted that left-handers are less common among senior citizens. Three main reasons have been proposed to explain this finding; one of which is Coren and Porac's hypothesis that left-handers are not common in older age groups because they have died at a younger age. Before this hypothesis is discussed, the other possible explanations for the finding will be outlined and the reasons why Coren and Porac think they provide an inadequate explanation for the disproportionate rarity of left-handers in the older age groups.

3.2.1 Cultural Pressures

All of the studies that have examined handedness and age have been cross-sectional. This means that older subjects were born when there was a lot of pressure against the use of the left hand and left-handers were encouraged or forced to use their right hand especially for writing. A number of authors (e.g., Brackenridge, 1981; Brito et al., 1989; Fleminger et al., 1977) claim that the smaller proportion of left-handers in older age groups merely reflect the historically greater social sanctions against left-handers and the increasing numbers found in younger age groups are due to the greater social and educational tolerance for left-handedness more recently.

3.2.2 Increasing use of right hand with age

This explanation proposes that the increase in right-handedness in older age groups is due to people becoming more right-handed as they age. This is known as the right-sided world hypothesis (Porac and Coren, 1981). It begins with the observation that many tools and much equipment and many everyday household items are manufactured for the convenience of the right-hander and the inconvenience of left-handers. Scissors, can-openers and hockey sticks are just three examples of implements designed for use with the right-hand (see Coren, 1992 for a long list of others).

It is argued that as a result of this right-sided bias in the world, left-handers are forced to do many things with their right hand that right-handers are never be expected to do with their left. The consequence of this is that a left-hander may be gradually modified by covert pressure to use the right hand and will eventually become a right-hander (Coren and Halpern, 1991). This would result in a reduction in the numbers of left-handers in older age groups.

3.2.3 Coren and Halpern's (1991) reasons for rejecting the modification hypothesis

Coren and Halpern (1991) group the cultural pressures and right-sided world hypotheses under the label 'modification theories'. In other words there are fewer left-handers in older age groups because they have been modified to become right-handers as distinct from having been eliminated through earlier death (Coren and Halpern's hypothesis). Although Coren and Halpern acknowledge factors such as cultural pressure may have some influence on the numbers of left-handers in older age groups, they argue that these factors alone do not explain the large differences they found between the proportions of left-handers among old and young subjects. The reasons they put forward are as follows:

1 Over long periods of time the numbers of left-handers in the population have remained stable and have not increased as the cultural hypothesis predicts. For instance Coren and Porac (1977) examined artistic representations of handedness in a sample of 1,180 works of art spanning a 5,000 year period. They found that the number of left-handers remained fairly constant over the time span at approximately 8%. However the range of left-handedness reported in these works varied from 3% to 14% which covers the range of left-handedness found today in societies that do and do not place pressure on left-handers.

Porac, Coren & Duncan (1980) examined 34 studies that were published between 1913 and 1976 measuring the incidence of left- and right-handedness. They reasoned that if cultural and social pressures had subsided over the years then this would be reflected in the percentages of subjects classified as left-handed and there should be fewer left-handers in older studies.

Although the studies that reported the highest numbers of left-handers were the more recent ones, the correlation between year of publication and percentage of right-handedness was $r = -0.28$ which was not statistically significant. Coren and Halpern (1991) claim that this is not a big enough change to explain the dramatic reduction of left-handers in older age groups. It would be interesting though, to examine population studies conducted since 1976 to see if the trend towards higher rates of left-handedness continues.

Unfortunately Porac, Coren & Duncan (1980) did not provide details of the 34 studies they used, nor did they outline the type of samples or the measures utilized, other than to say that they were preference measures used on western, Caucasian adult subjects. As was outlined in Chapter One, different preference measures can have a marked effect on the proportion of right-, left- and mixed-handers that are found.

2 The basis of the cultural pressure hypothesis is that in the past many natural left-handers were forced to use their right hand and so older left-handed subjects appear as right-handers in studies on the incidence of handedness. Coren and Halpern (1991) argue that attempts to change left-handers are difficult and are not numerous enough to account for the dearth of left-handers among older subjects.

Coren and Halpern (1991) also try to discredit the modification hypothesis by arguing that their data show a trend towards increasing right-handedness with age and that this cannot be explained by an individual's handedness being changed when they are adults because this is very hard to achieve. Most successful hand switches occur before the individual is nine years old. However this only discredits the right-sided world hypothesis, not the cultural pressure one. It is still possible for the decrease in left-handedness to have occurred because more in the older than younger age groups had their hand preference changed when they were young.

Coren and Halpern (1991) appear to regard their data as showing an adult trend towards greater dextrality as if the study was longitudinal (see p. 93). However, their data are cross-sectional and all it can be said to show is that of their subjects who were over 80 years of age, none were left-handed while 15%

of younger subjects were. It does not mean that those 15% will be right-handed by the time they reach 80.

3 The final argument that Coren and Halpern put forward against the modification hypothesis is that handedness shifts, when they do occur, are usually quite specific to a single activity and they do not generalise to other tasks (Tambs et al., 1987). Therefore questionnaires involving a number of preference items should still be able to assess people as left-handed if they have been forced to use the right hand only for writing.

The evidence in this area is mixed. Harris (1990) outlines studies (e.g., Teng, Lee, Yang & Chang, 1976) that show left-handers switched to the left for eating and writing still use the left hand for other tasks. However others (e.g., Tan, 1983) have found differences in the percentage of subjects performing tasks left-handed, between younger and older subjects, for items such as hammering and using a toothbrush, which are not likely to be the subject of training. The influence of pressure and training on hand use is an area that still needs to be researched in order to ascertain the circumstances under which a person may or may not learn to use a particular hand for a task.

To summarise, Coren and Halpern have put forward a number of reasons why the modification hypothesis cannot account for the dearth of left-handers in older age groups. However by grouping the cultural pressure hypothesis and the right-sided world hypothesis under one heading, they try to discount both of them when really only using evidence against one.

It may be correct to discount the right-sided world hypothesis that assumes left-handers become right-handed over their life span. After all, if left-handers have to become more proficient at using the right hand, then surely they would be more likely to become mixed handers, being good at using both hands, rather than just the right hand to the detriment of the left hand. Another alternative is that they may show attributes similar to the so-called inconsistent left-handers (Peters, 1989). They may perform some culturally biased tasks well with the right hand while continuing to use the left hand for others. It is possible that some left-handers forced to use the right hand to write with do learn to do other tasks with the right hand. However there is evidence that many of those forced to write with the right hand still use the left for other tasks.

While the right-sided world hypothesis may be discounted, this is not the case for the effect of cultural pressure. There are many reports of left-handers being switched to use the left hand and the relaxing of this pressure and the subsequent increase in numbers of left-handers in western countries provides evidence of the effect that this has had on the number of left-handers found in certain populations (e.g., Brackenridge, 1981). Two studies in particular provide evidence of the effect of cultural pressure on the incidence of handedness.

3.3 RECENT EVIDENCE FOR THE CULTURAL PRESSURE HYPOTHESIS

Gilbert and Wysocki (1992) obtained handedness data from 1.17 million American men and women ranging in age from 10 to 86 years. Subjects were asked what hand they wrote and threw with. Eighty-nine percent of respondents were right-handed for both tasks and 11% showed evidence of left-or mixed-handedness. For both sexes left-handed responses were most prevalent in those aged under 30 (14% for men, 12% for women) and least prevalent among those aged over seventy (near 6% for both sexes).

The left-handed sample comprised three groups. These were left write and throw (LwLt), left write, right throw (LwRt) and right write, left throw (RwLt). When these sub populations were examined separately, it was found that the relative proportion of each sub-group changed across age cohorts. The population of LwLt declined with age to about 2% for those aged between 50 and 80. RwLt comprised between 1 and 2% of the younger population but in subjects aged 70 and over it was the most common left-handed phenotype with over 4% of the sample demonstrating this phenotype.

Gilbert and Wysocki (1992) conclude that these findings are consistent with the cultural pressure hypothesis. It can be assumed that large numbers of the sub-group RwLt are left-handers who have been forced to write with the right hand while maintaining a left hand preference for the less culturally sanctioned task of throwing. This would explain why there are higher rates of this sub population in older age groups. In contrast the LwLt phenotype reduces with age because a proportion of these subjects would have had their writing hand changed, especially in the older age groups, but this does not occur as often now.

This study poses problems for the mortality hypothesis of Coren and Halpern (1991). It cannot explain why the RwLt prevalence increases rather than decreases with age (Gilbert & Wysocki, 1992). In favour of the mortality hypothesis, the combined group of left-handers do decline with age. However the LwRt group comprises 4-5% of the younger population but only 1% near age 70. If these people had their hand changed for writing, their phenotype will be RwRt and this could lead to an apparent reduction in the number of left-handers in older age groups, possibly by 3-4%.

A study by Hugdahl, Satz, Mitrushina and Miller (1993) looked specifically at the rate of hand switch amongst left-handers. Their results from 2,787 subjects showed the usual decreasing prevalence of left-handedness across the age span with 15% in the youngest group (21-30 years) but only 1.7% in subjects older than 80 years. There was however a corresponding increase in the number of subjects who said they had had their hand switched for writing from 2.7% in the youngest group to 6.75% in subjects 80 years and older. In subjects aged over 80, more than half of the left-handers had been switched.

Hugdahl et al. (1993) propose that the decrease in left hand use over age was counteracted by a corresponding increase in hand switching. They do acknowledge that when hand switchers are included as left-handers there are still fewer left-handers in older than younger age groups (about 5% difference). It is possible that a younger age at death by some left-handers may be the cause of this difference.

Coren and Porac (1991) do acknowledge that the cultural pressure hypothesis could account for some of the difference between the proportions of left-handers in older and younger age groups. However they claim that it, "cannot explain the shift in the percentage of left-handedness from nearly 15% at age 10 to virtually 0% at age 80" (p. 93).

Not all studies though, have found a difference as large as Porac and Coren (1981) did in the number of left-handers in older and younger age groups. For instance, Gilbert and Wysocki (1992) using a much larger sample size found a difference of only 8% for men and 6% for women between those aged under thirty and those over 70. If the difference in the proportion of left-handers in older and younger age groups is actually smaller than that found by

Porac and Coren (1981), then cultural pressure could very well explain a large portion of the difference.

Coren and Halpern's (1991) alternative to the cultural pressure hypothesis is the elimination hypothesis. This proposes that left-handers are unavailable to be measured in older age groups because they have died earlier.

3.4 MORTALITY STUDIES

Coren and Halpern have conducted two major studies to provide evidence that left-handers do die at a younger age. The first of these was an archival study on baseballers and will be discussed shortly.

The second used a random sample of recently deceased subjects for whom age at death could be ascertained (Halpern & Coren, 1991). Next of kin were contacted to provide information as to what hand the deceased subject had used for writing, drawing and throwing a ball. Two thousand, eight hundred and seventy five letters were sent out, of which there were 987 useable returns. This represents a response rate of only 34%.

The percentage of left-handedness reported by the next of kin to ranged from 5.8% for writing to 7.3% for throwing. Coren and Halpern (1991) acknowledge that these figures are lower than would be expected and cite their own evidence (Porac and Coren, 1979) showing that people (even those who live with left-handers) under report the incidence of left-handedness. Despite this, and the low return rate, they take this study as support for their mortality hypothesis.

Subjects were classified as right-handed if they performed all three activities with the right hand and the left-handed group contained both left- and mixed-handed individuals. The results obtained were as follows: the average age at death for right-handers was 75 years of age while the average age of death for the left-handers was 66 years. The left-handers' life span was on average nine years shorter. It was also found that the effect of left-handedness was greater for men. While there was an average of a five year age gap between right-and left-handed women, the gap was over 10 years for men.

This study has created considerable interest and controversy. Critics of the study argue that Halpern and Coren never ascertained the age distribution for left- and right-handers in the area they sampled. Their results may reflect the fact that the average left-handed person in the United States is significantly younger than the average right-hander due to the reduction in social pressure against left-handedness. Since the population of left-handers is younger, the left-handed people who die will, on average, be younger than right-handed people who die (Hartge cited in Charles, 1991 and Holden, 1991). Salive et al., (1993) claim that for the data of Halpern and Coren to be informative, information on the age specific prevalence of handedness in the general population is required.

A study with such important implications as this is surely in need of replication. However, given the ethical problems encountered by Halpern and Coren (outlined in Coren, 1992) and the inherent problems of relying on information from next of kin, interest has focused on the replication of their other elimination evidence; the baseball study.

The baseball study (Halpern & Coren, 1988) involved collecting information about the birth and death dates of baseball players in the United

States major league up until 1975. These statistics were used because baseball data is one of the few written sources of information on a person's handedness. This is in the form of information about a player's batting and throwing hand.

Subjects were counted as right-handed if they both batted and threw right-handed. Similarly those described as left-handed, batted and threw with their left hand. Individuals who changed handedness or were mixed-handed were not included. This classification resulted in 1,472 right-handers and 236 left-handers for analysis.

Mean age at death reported for the right-handers was 64.64 years (SD = 15.5) and 63.97 (SD = 15.4) for the left-handers. Although Halpern and Coren (1988) do not report it, application of a t-test indicates the means do not differ significantly. Rather, Halpern and Coren (1988) suggested the result was difficult to interpret, and a t-test not appropriate because the range was so large (age at death varied from 20 to 109 years), the distribution was skewed, (they gave no information on the amount of skew), and there were large differences in sample size. They argued that the data were more suitably treated by a nonparametric statistic, the Wald-Wolfowitz Runs Test (Siegel, 1956). By this test the two groups were significantly differently, they argued, in favour of greater longevity for the right-handers. It was also found that fewer than 0.5% of the left-handers survived to the age of 90 compared with more than 2.5% of the right-handers. This difference was found to be significant using the Moses Test of Extreme Reactions (Siegel, 1956).

Halpern and Coren (1988) also examined the data in terms of the cumulative proportion of individuals surviving at each age from each handedness group. They found that the two groups were virtually identical in mortality until the age of 33. From that age onward, the percentage of right-handers who survived averaged around 2% higher than the corresponding percentage of left-handers at each age. Coren and Halpern (1991) sought to use this information in a statistical test. They observed that in 52 of the 58 yearly age groupings where the cumulative survival percentages differed by more than .5%, right-handers had the higher survival percentage. This they stated was a statistically significant result in favour of greater longevity of the right-handers, although no test was mentioned. One can only assume that a binomial test had been used. It is however inappropriate to use this since the differences at age of death in the cumulative distribution were not independent.

Like the next of kin study, the data and methods that Halpern and Coren (1988) used in this study have come under criticism. Wood (1988) argued that the Kolomogorov-Smirnov test (Siegel, 1956) was more appropriate to the baseball data. When it is applied to Halpern and Coren's data it predicts that even if there were no difference in the mortality distributions of left-and right-handers, a difference in the cumulative survival fraction larger than that found by Halpern and Coren (1988) would arise by chance in 98 out of 100 samples.

Wood (1988) also collected a large sample of baseball players (2,829 right-handers and 645 left-handers) and concluded that there was not a statistically significant difference between the mortality of left-and-right-handed baseball players using the Kolmogorov-Smirnov test. When this more appropriate and powerful test is applied to baseball data, a significant difference fails to eventuate.

It appears that the Wald-Wolfowitz Runs test was inappropriately applied to the baseball data. The runs test is designed to reject the null hypothesis if the two populations differ in any way, such as location, variability, skewness or kurtosis (Siegel, 1956). It was therefore incorrect for Halpern and Coren to assume that a significant result from the runs test necessarily meant that right-handers lived longer. It could have been indicating that the distributions of age at death differed in skew or kurtosis for example.

Anderson (1988) notes that both Wood (1988) and Halpern and Coren (1988) analysed their data unadjusted for birth date. Obviously if one group is born significantly earlier or later than the other, then this will have an effect on age at death. For instance better medical care and treatment have improved life expectancy over the years.

Therefore it is inappropriate to compare left- and right-handers in a sample born over a long period of time because it will be comparing subjects who had different life expectancies. Any type of statistical test will yield worthless results if it is used to compare subjects as a whole sample. The only way then to determine if left-handers die on average younger than right-handers is to ensure that subjects have comparable birth dates, which is what Anderson (1988) has done.

Like Halpern and Coren (1988) and Wood (1988), Anderson (1988) also collected data on baseball players. He used throwing hand as the indicator of handedness and obtained 4,479 subjects in total (proportions of left and right throwers were not given). He formed birth cohorts based upon a minimum of 25 left-handers and this resulted in 23 groups which each included between 25 and 50 left-handers.

Within each cohort, the mean age of death of the left-handers was subtracted from the mean age at death of the right-handers (R-L). Anderson (1988) found that over all of the cohorts the mean R-L difference was zero which meant that there was no difference between left-and right-handed mortality. When a graph of R-L was plotted against the mean birth date of the cohort it was found that R-L decreases from around a three year advantage in favour of right-handers in 1868 to zero by 1890. After this time left-handers have the greater mean age at death. From a regression equation left-handers are predicted to eventually outlive right-handers by about 3.7 years on average.

The conclusion from this is that for people born before 1890, right-handers are more likely to live longer while of those born after this time it is left-handers who have increased longevity. It follows that whether a difference in mean age at death is found between left-and right-handers will depend on the proportion of the sample born before or after 1890.

Anderson (1988, 1989 cited in Weiss) suggests that left-handers now live longer because they have had to be hardier to survive in a world designed to advantage right-handers. With discrimination against left-handers declining in western countries, the hardiness of left-handers will be translated into longer life expectancy. Coren disagrees and claims that there is little evidence that left-handed life is any less dangerous today than in previous times. He also argues that since Anderson only used throwing hand as the criterion for handedness he will not have excluded ambidextrous individuals (cited in Weiss, 1989).

3.5 PRESENT STUDY

The aim of the present study is to conduct an archival study similar to Halpern and Coren's (1988) baseball study using a sample that is different yet comparable to the baseball sample. As mentioned previously, it is quite difficult to obtain accurate records giving age at death and handedness for large numbers of people. Baseball was a sport that kept these records and cricket is another which records the hand a player bats and bowls with. In many respects a cricket sample will be very similar to the baseball samples. It is male, by and large healthy, and handedness measures are obtained during early adulthood when handedness is well established. There is also potentially a large pool of subjects spread out over many years so that the effect, if any, of year of birth can be established. A difference between the two samples is that the baseball studies have been based on American subjects, while the study of cricketers to be reported uses subjects who were born, or lived a large portion of their lives in England.

In some respects the present sample of cricketers may be more representative of handedness in the population than those using baseball statistics. For instance, Halpern & Coren (1988) and Wood (1988) report over 18% of their respective samples as left-handed. This seems rather high when compared to population studies (e.g., Thompson & Marsh, 1976; Salmaso & Longoni, 1985) and may be because there is a well known advantage in baseball for left-handers (their batting stance on home plate is closer to first base than the right-handed stance). This advantage may mean a higher than expected number of left-handers playing baseball and it may have encouraged some right-handers to change hands. There is no such advantage in cricket apart from the element of unfamiliarity that all left-handers possess when they oppose right-handers in sport.

A problem with this type of study is that the measures used may not provide a completely valid indication of handedness. As was shown in Chapter One, what constitutes handedness and how it should be measured is a difficult issue. The problem in both the baseball studies and the present one, is that the measures used to assess handedness are indirect because there is no way of knowing for sure whether a person who bats and bowls left-handed will perform other tasks with the left-hand as well.

Wood (1988) argued that throwing hand was an accurate indicator of handedness because while there are switch hitters in baseball (players who can bat left-or right-handed) there is only one recorded instance of a switch thrower. Research would appear to support this claim. Studies almost unanimously report that throwing rates highly for reliability (e.g., Coren & Porac, 1978; Raczkowski et al., 1974), validity (in terms of factor structure) (Steenhuis et al., 1990) and real life behaviour (Raczkowski et al., 1974). Others recommend its use (e.g., Humphrey, 1951) because it is not subject to as much cultural pressure as writing.

However the finding of Peter and Servos (1989) that some left-handers use the right hand for throwing suggest that the use of throwing hand alone as a criterion of handedness may miss some of these inconsistent left-handers. However, as will be shown, a person who bats left-handed and bowls right-handed may not necessarily be a left-hander either.

Batting hand is the other measure used to assess handedness. However this item does not appear to be as useful an indicator of handedness as bowling or throwing. While Raczkowski et al. (1974) and Liederman & Healey (1986) found that baseball batting hand had reasonably high test-retest reliability, Chapman and Chapman (1987) found that this item did not correlate very highly with other preference items.

As outlined in Chapter One, both Steenhuis and Bryden (1989) and Liederman & Healey (1986) reported that factor analysis found the item 'baseball bat' to be a factor separate from so-called general handedness factors. Both studies also found that batting was characterised by a relatively high rate of non-preferred hand use. Plato et al. (1984) found that batting had a low level of concordance with other preference items and they reasoned that it may not be measuring the same attribute as items such as writing or throwing. They suggested that this was because it was two-handed and involved whole body movement.

Batting in cricket is similar to baseball batting in that it is two handed and involves whole body movement. Humphrey (1951) also found that like baseball batting, cricket batting shows a high rate of non-preferred hand use. Of his sample of left-handers, he found that 70% used a cricket bat right-handed. Wood and Aggleton (1989) declared that the batting hand of cricketers was a poor indicator of handedness. They sent the EHI to 45 professional cricketers who batted left-handed. Of the 25 replies received, 23 scored as right-handed on the EHI.

It appears then that the batting hand for baseball and cricket may not be a very useful indicator of handedness. However in the present study, batting hand is used in conjunction with bowling hand as an assessment of handedness. Since Halpern and Coren (1988) used both batting and throwing, it was decided to include both in this study to make the results comparable to theirs and overcome their objection to Anderson's (1988) analysis that used throwing hand only. It is also hoped that by having people who bat and bowl left-handed categorised as left-handed that only those who are strongly left-handed will be included, reducing the chance of any right-handers being included in this group.

The original intention of this study was to examine the relationship between handedness and age at death for mixed-handers as well as left- and right-handers. However it was decided that since batting and bowling are only indirect measures of handedness, no definitive conclusions could be drawn from mixed-handed samples because their true handedness could only be guessed at. Instead, the groups 'right bat and bowl' and 'left bat and bowl' are used to obtain the most distinct left- and right-handed groups possible.

To summarise, the studies suggesting that left-handers die at an earlier age are controversial. The aim of this study is to provide results that will help to resolve the debate on this contentious issue.

CHAPTER FOUR

METHODOLOGY

The date of birth, date of death, batting hand and bowling hand of first class male English cricketers, who died between 1764 and 1991 was sought. A first-class cricketer was defined as one who had played in the 1st XI of one or more of the thirteen first class counties in England and Wales, the Marylebone Cricket Club (MCC), Oxford or Cambridge University.

Information on the subjects was obtained from archival sources in the form of books and magazines. The main source was the book "Who's who of cricketers" (Bailey, Thorne & Wynne-Thomas, 1984). This volume listed the birth date, death date, batting and bowling hand for every cricketer who had played first class cricket in England and Wales up until the date of publication. The cause of death was not listed in every instance but was recorded when it was.

A number of other books and magazines were used to supplement this information. Recently published books detailing the history of approximately half of the counties included in the study were available (see Appendix A). These contained a list of all the cricketers who had played for that particular county, together with the day, month, year of birth and death where applicable.

For counties that did not have recent histories available, the Wisden Cricket Almanacks (published yearly) and the obituary section of the monthly magazine "Cricketer International" were used to obtain birth and death dates.

Where a cricketer was recorded in more than one source, the details were compared to verify that they were accurate. Once this was done a player was marked off in the "Who's who of cricketers" (Bailey, Thorn & Wynne-Thomas, 1984) to minimise the chance of their being recorded twice, if for example, they had played for more than one county. The "Who's who" was the only comprehensive source of batting and bowling information, but if this was lacking or the birth or death dates conflicted with another source, then the player was excluded. Ten players labelled as ambidextrous were also excluded leaving 4.279 players for analysis which was 73% of all subjects available.

CHAPTER FIVE

RESULTS

The age at death of the subjects ranged from 19.7 years to 103.9 years with a mean of 66.2 years (SD = 16.6). Subjects were classified into eight groups according to batting and bowling hand. Subjects who were left-handed for batting and bowling comprised 4.77% of the subjects and 14.7% of subjects performed at least one function left-handed.

An examination of Table 1 shows that the two mixed-handed groups had the highest mean age at death, followed by the three groups comprised of right-handers (RR,R-,-R) while the left-handed groups (LL,L-,-L) had the lowest means.

Table 1

Mean age at death for subjects grouped according to batting and bowling hand

Handedness	Mean age at death	N	SD	Range
Right bat and bowl (RR)	**66.6**	**1861**	**16.1**	**19.7 - 99.0**
Right bat only (R-)	66.4	1744	16.7	20.1 - 103.9
Right bowl only (-R)	64.0	42	18.2	24.7 - 89.7
Left bat and bowl (LL)	**62.5**	**204**	**17.0**	**25.8 - 92.6**
Left bat only (L-)	62.4	87	18.3	25.6 - 88.9
Left bowl only (-L)	61.4	67	17.3	23.4 - 89.2
Right bat left bowl (RL)	67.3	191	17.3	22.3 - 96.2
Left bat Right bowl (LR)	67.7	83	15.6	26.16 - 93.9

A comparison of the two major groups (RR and LL) found a significant difference in age at death $\underline{t}$ (2063) = 3.45, $p < 0.001$ in favour of the RR's. The right-handers' mean age at death was 4.13 years higher than the LL's. The oldest surviving RR lived to 99 years of age while the oldest left-hander lived to 92.6 years, a difference of 6.4 years. Only 0.98% of LL's lived to over the age of 90 years while 2.6% of RR's lived beyond this age. A Wald-Wolfowitz Runs test (used by Halpern & Coren, 1988) was nonsignificant, z = 1.88, $p < 0.06$ ns and a Kolomogorov-Smirnov (recommended by Woods, 1988 for this type of data) was also nonsignificant z = 1.51 $p < .13$ ns.

The effect of having different birth cohorts in the sample was assessed using Anderson's (1988) method. Subjects were grouped into birth cohorts based upon a minimum of 25 LL's in each group. This resulted in eight birth cohorts but subjects from the most recent one (1911-1939) were excluded because it contained only 16 LL's. Also many cricketers born during this time are still alive, thus data from this group give an artificially low mean age at death. The remaining seven cohorts ranged from a birth year of 1791 to 1910 and each group contained between 25 and 31 left-handers. As a further comparison, data were also calculated for the group, right bat only (R-), to ascertain if any differences between the right- and left-handed groups would be found consistently. Data from RR's and R-'s who were born in years where no LL's were born were not included in the analysis.

Figure 1 shows the difference in mean age at death for the two groups of right-handed subjects compared with the LL's. It shows that the difference in age at death is approximately eight years for each of the first two cohorts in favour of the right handers. This drops over next two cohorts but there is a sudden rise during the 1883-1891 cohort to approximately 12 years. After this the difference in mean age at death drops again until, by the final cohort, the difference in mean age at death drops below zero, signalling an advantage to the left-handers.

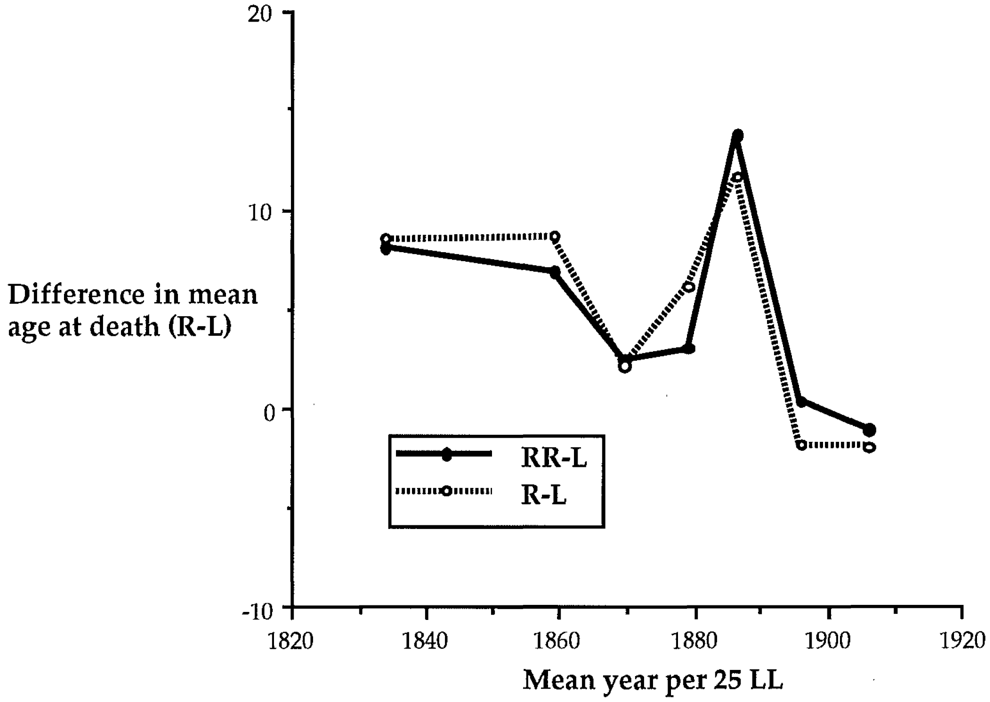

Fig 1: The difference in mean age at death (R-L) of RR and R- compared to LL's as a function of birth cohort.

Figure 2 shows that the mean age at death for the two groups of right-handers remains fairly constant over the years. In contrast the left-handed group's mean age at death is considerably lower in the first two cohorts but increases to be comparable to the right-handers by the final cohort. It can be seen that the large increase in R-L in the cohort 1883-1891 (see Fig. 1) results from the fall in age of the LL's rather than an increase in the right-handers age at death.

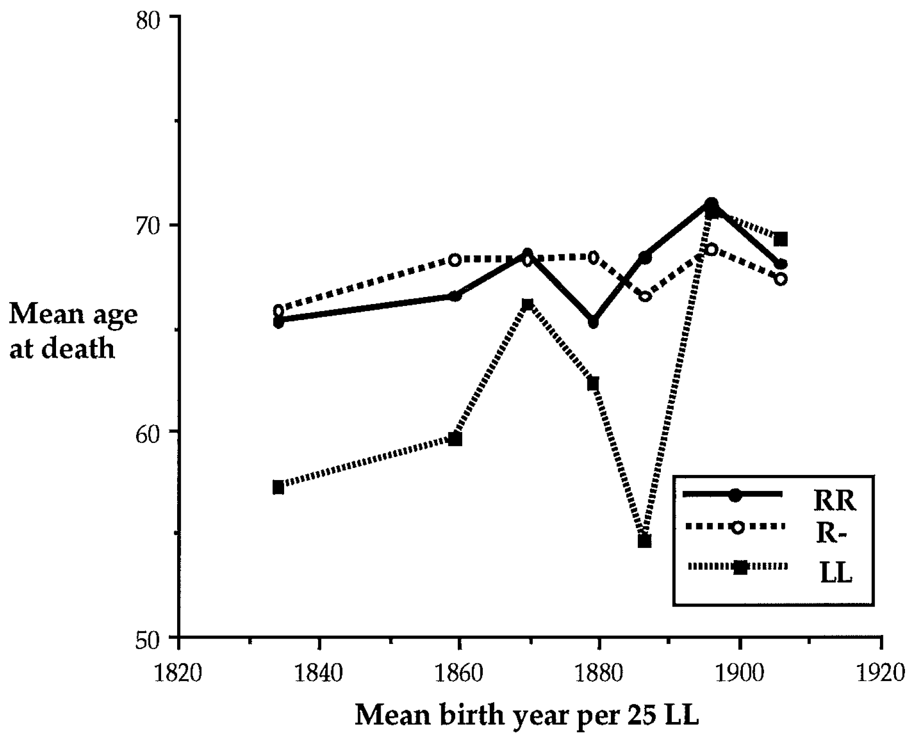

Fig 2: Mean age at death of RR, R- and LL as a function of birth cohort.

It was hypothesised that since subjects born in the cohort (1883-1891) were in early adulthood during the first world war (1914-1919), the sudden drop in the mean age at death for the LL's may have occurred because proportionally more of them were killed in action. Figure 3 shows the mean age at death for RR's, R- and LL's when those who were killed in action are excluded from analysis. To retain 25 LL's in each cohort there was a reduction in the number of cohorts from seven to six but it is still apparent that the dramatic drop in the mean age at death of the LL's disappears when those killed in action are excluded.

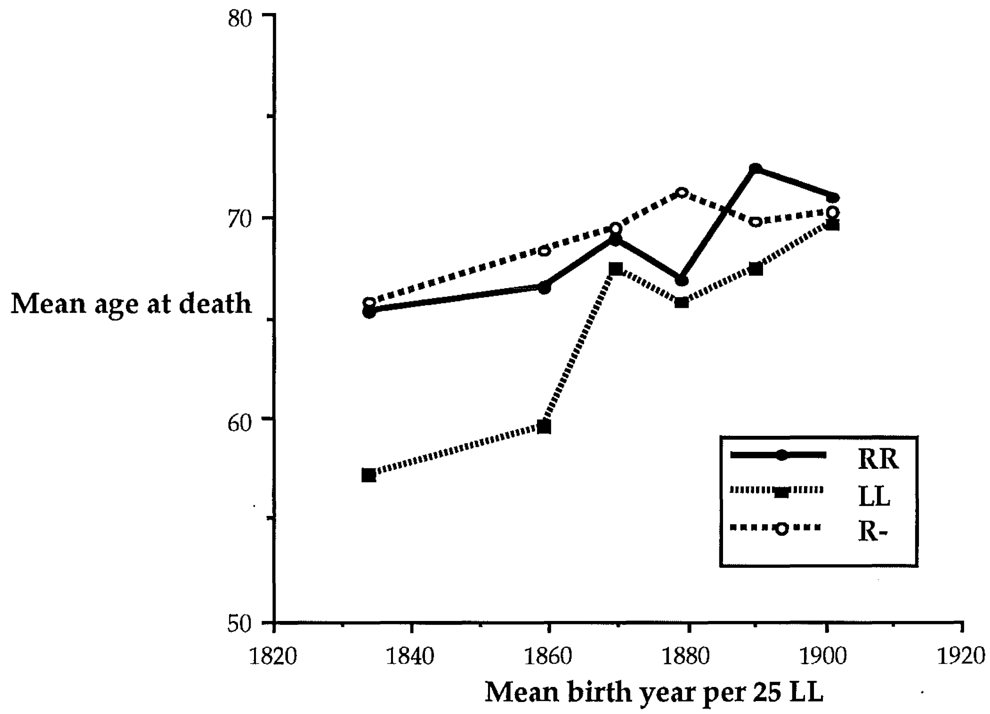

Figure 3: Mean age at death for RR, R- and LL when those killed in actiion are excluded.

An examination of Figure 4 shows the difference in mean age at death between RR and LL's when those killed in action are excluded from analysis. A gradual decline in the difference between mean age at death is apparent. A linear regression, RR - LL = 11.57 - 0.94 (YOB- 1791)/10, $R^2 = .524$ was nonsignificant $F(1,4) = 4.41$, $p < .10$ but is in the expected direction. The graph shows that when those killed in action were excluded, there is a decline in the difference in mean age at death between RR and LL's of approximately one year per ten birth years.

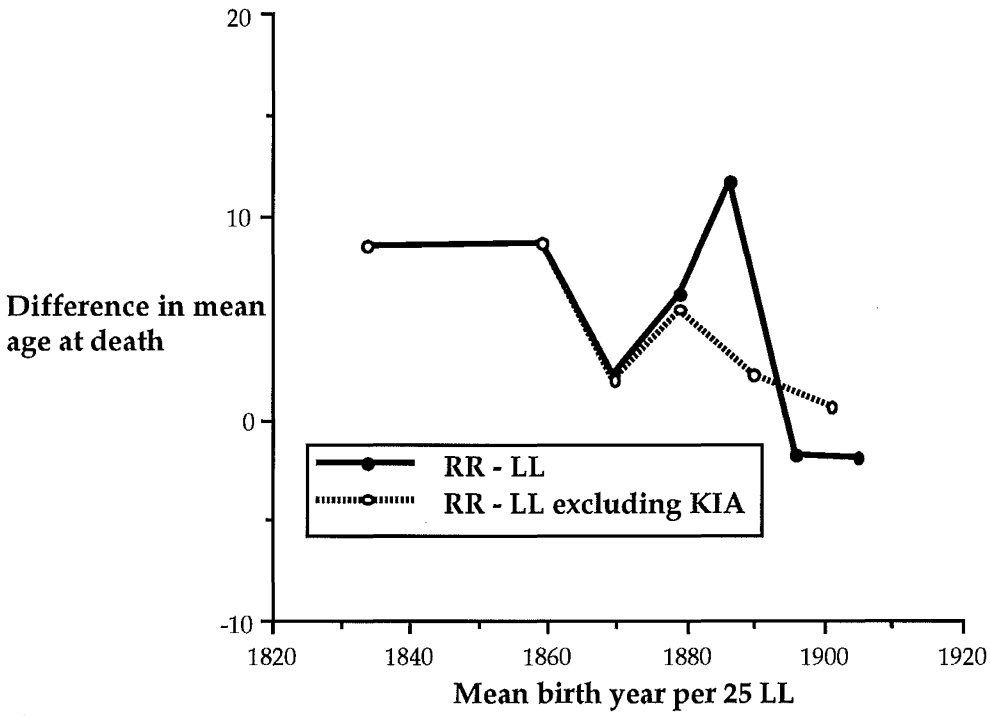

Figure 4: Difference in mean age at death (R-L) with and without those killed in action (KIA).

To ascertain the reason for the decrease in mean age at death of LL's in birth cohort (1883-1891) the mean age at death for all cricketers killed during World War 1 was obtained. The birth years of those killed in action ranged from 1868-1896. Table 2 provides the mean age at death and the percentage of those born in these years who were killed in action.

Table 2

Mean age at death and percentage of those born 1868-1896 who were killed in action in World War I

Handedness	Mean age at death	No. killed	No. born 1868-1896	% killed in action
Right bat and bowl (RR)	30.32	34	701	4.85
Right bat only (R-)	32.23	47	680	6.91
Left bat and bowl (LL)	32.10	10	89	11.24

It is apparent that the left-handers who were killed in action were not any younger than the right-handers but a higher proportion of LL's born in this era were killed in action. Overall, left-handed cricketers were twice as likely to have been killed in World War I as their right-handed counterparts, ^{2} (2) = 6.68, $p < .05$.

Finally, the proportion of the sample classified as LL increased over the birth cohorts in this study when compared to the RR's. The number of left-handers was 9.47% in the first cohort (1791-1851) and rose to over 14% in the final cohort (1901-1909). A linear regression, $\%LL = 1.65 + 0.4(YOB - 1791)/10$, $R^2 = .798$, $p < .01$ was significant indicating that the proportion of cricketers labelled LL rose by 0.4% each ten years.

CHAPTER SIX

DISCUSSION

As stated in the introduction, the aim of this thesis was to conduct a study similar to Halpern and Coren's (1988) baseball study. They claimed to have found that left-handed baseball players were more likely to die at a younger age than their right-handed counterparts. The present study used a similar methodology to Halpern and Coren (1988) but used the archives of English first class cricketers. Discussion of the results of the present study will begin by analyzing the major findings and how they compare with those of Halpern and Coren (1988) and Anderson (1988). Limitations involved in using the archival method will be outlined as well as more general criticisms of left-handedness research as it currently stands. Finally some directions for future research are proposed and comments made on the myth of laterality and how it appears to have affected research in this area.

6.1 DO LEFT-HANDERS DIE YOUNGER? RESULTS FROM THE PRESENT STUDY

As pointed out in the introduction, it is inappropriate to interpret Halpern and Coren's (1988) data and results from the present study using methods which ignore year of birth. This is because the birth date of the subjects concerned span a large period of time (over 200 years in the present study) and during this time life expectancy increased.

If the data are analyzed without taking the year of birth of subjects into account then the results found will not give a true comparison between left- and right-handers. For example, in the present study a difference in mean age at death of 4.13 years in favour of right-handed cricket players was found. If the data had only been analyzed in this way then this result could have been interpreted as support for Halpern and Coren (1988). In reality this result could have been an artefact due to proportionally more left-handers in the current study being born in earlier years when life expectancy was lower.

It follows from this that it does not matter whether parametric, nonparametric or cumulative frequency distributions are used to interpret the data in this form. They are all inappropriate if used to analyze the sample as a whole. The only appropriate way to analyze the data is to compare subjects who were born during similar time periods, as Anderson (1988) has done.

When subjects were grouped according to Anderson's (1988) birth cohort method, the present study found that right-handed cricket players born before the late 1880's had an advantage in terms of life expectancy, but this subsequently diminished, until there was a slight advantage to left-handed players, in mean age at death, for those born between 1901 and 1909. The findings from the present study are similar to those of Anderson (1988). In his sample, right-handers born before 1890 had an advantage, but this subsequently decreased. He estimated that for those born in 1910 there would be an advantage in terms of longevity of approximately two years in favour of left-handers.

To explain this finding, Anderson (cited in Weiss, 1989) suggests that along with left-handedness there evolved other unrecognized genetic traits that helped to compensate left-handers for the cultural and physical biases inherent in a world dominated by a right-handed majority. In western countries at least, there is now less pressure against being left-handed, and so left-handers may now live longer due to the survival advantages that they possess. Anderson does not suggest what these traits may be but Geschwind and Galaburda (1987) suggest that left-handers may have lower rates of certain diseases such as cancer.

Coren and Halpern's (1991) explanation of decreased survival fitness has trouble dealing with the finding that left-handers used to die younger but now apparently do not. If left-handers are weaker due to immune deficiencies, maturational processes or something else, then why have these factors had an effect at one point in history but not in another? Unfortunately the results from the present study and those of Anderson (1988), are based on a select group of top class sportsmen, so it is not known whether the results found generalize to left- and right-handers in the population at large.

One way in which cricketers may be different from the general population is in their level of health and fitness. For subjects to have been able to play first class English cricket required that they had a certain degree of health and stamina. This means that the sample used in the present study may be healthier than the general population and is therefore unlikely to include any so-called pathological left-handers, whose inclusion may have an effect on the mean age at death of left-handers.

Another limiting factor in the present study and those conducted using baseball players, is that the data is from players who, at the very least, had reached young adulthood. There is no way of knowing if, for any reason, either left- or right-handers have higher mortality rates during childhood, nor the effect that this may have on the mean age at death for each handedness group.

It is therefore not possible to conclude from this study that all left-handers on average, died younger than right-handers at one stage in history , but now do not. However this study does show that even though there was an overall disadvantage in terms of mean age at death (4.13 years) for left-handers over the whole sample, this was not the case when year of birth is taken into account. Halpern and Coren (1988) were not justified in concluding from their data that left-handers are more likely to die at a younger age because they failed to take year of birth into account.

Even though the findings from the present study and Anderson (1988) cannot be generalized, there are some interesting findings to be mentioned. For instance, both this study and Anderson (1988), using subjects from different countries, find that the difference between left- and right-handers diminished at approximately the same time. The time period in question (late 1800's) was one of great change in the United States and Britain brought about by the industrial revolution (Lenski & Lenski, 1970). A suggestion is that improvements in general hygiene and sanitation around this time (including child birth techniques) advantaged left-handers more than right-handers thereby enabling left-handers to close the age gap. If left-handers were weaker to begin with or had higher rates of certain ailments then any improvements in this area may have had a greater effect on their life expectancy. Related to this is the suggestion that left-handers may have been more susceptible to certain diseases or conditions than right-handers but the late 1800's saw the development of procedures to eradicate or control these, thus allowing left-handers to live longer.

While the industrial revolution saw the development of new industrial machinery most probably designed for right-handers, the sample used in this study is unlikely to show the effect of industrial accidents on left-handers because cricketers tended to come from middle and upper class backgrounds and would not have encountered these conditions. Cricket in England is traditionally played by those in the middle and upper classes and is very strong in English public schools. This bias is evident in the sample in this study as many were educated at Eton, Oxford or Cambridge.

If left-handers did die at a younger age at some point in time, but now do not, then the above ideas are suggestions to explain why this may have occurred. However it is not known if the findings from this study apply to the population at large.

An unexpected finding from the present study was that the proportion of left-handers killed in action was nearly double that of the right-handers, although the small numbers involved (10 left-handers), need to be borne in mind. One explanation consistent with Coren and Halpern's (1991) general stance, is that left-handed infantrymen in World War I might have been handicapped by using the Enfield rifle and Bayonet system designed for right-handers (Pugsley,personal communication, 1993). While using tools designed for right-handers may be an annoying inconvenience under normal circumstances, in war time it could be the difference between life and death. Even if it only took a split second longer for a left-hander to load a rifle it might mean he was vulnerable to attack.

No left-handers and only ten subjects who batted and bowled right-handed were killed in action during World War II. Hence it is unclear whether the result found for World War I was an artefact or whether left-handers are more likely to be killed in the particular kind of action involved in World War I. It is an area that possibly warrants further investigation although, as pointed out in the introduction, there is little point trying to compare left- and right-handers until there is more understanding of what handedness actually is.

To summarise, Halpern and Coren (1988) were not justified in concluding that left-handers are more likely to die at a younger age than right-handers because they did not take into account when subjects were born. A lower mean age at death for the left-handers in their sample may merely reflect that a greater proportion of them were born in years when there was a lower life expectancy. When the birth years of subjects are taken into account using Anderson's (1988) birth cohort method in the present study, an overall disadvantage of 4.13 years in terms of age at death for left-handers diminished to near zero by the early 1900's.

Suggestions have been put forward to explain why left-handed baseball and cricket players may have died earlier but now no longer appear to and why they may have had a greater chance of being killed in action. However there is no way of verifying the suppositions using the data from this archival study. The next section will outline other limitations involved in using archival research.

6.2 LIMITATIONS OF ARCHIVAL RESEARCH

A problem inherent with archival research such as that undertaken in the present study and that of Halpern and Coren (1988) is that other people have collected the original information and so there is no guarantee that it is accurate. Halpern and Coren (1988) used only one source to obtain data on baseballers. In the present study cross-checking was conducted using a variety of sources, particularly for birth and death dates and where differences were found, players were excluded from analysis. Information regarding batting and bowling hand was only obtainable from one major source (Bailey, Thorne & Wynn-Thomas, 1985). This source was found to be the most accurate for other data and the author has confidence that it was for batting and bowling information as well. This is because being left-handed for batting or bowling is unusual in cricket and is likely to be noted and commented on.

Another limitation of archival research is that one is dependent upon the type of data that is collected and additional information is often not obtainable. For instance, in the present study, the only indices of handedness available were batting and bowling hand. While these are useful indicators of handedness, there is always doubt as to whether they are providing an accurate picture of a person's handedness. For example David Gower batted left-handed but was right-handed for other tasks. This doubt meant potentially interesting data from mixed-handers (left bat and right bowl; right bat and left bowl) were excluded because there was no way of assessing what their true handedness situation may have been.

It is hard to find information on both birth and death dates and handedness in large numbers for males. For females it is practically impossible. Many studies have found that there are more left-handed males than females (e.g., Thompson & Marsh, 1976) and that there are differences between them on certain handedness measures (Kilshaw & Annett, 1983). This study therefore provides findings that are suggestive, but as yet no statements can be made as to whether the findings of the present study and that of Anderson (1988) apply to female left-handers or to whether they generalise to the male population as a whole.

Both this study and those discussed by Coren and Halpern (1991) used the traditional research method of separating subjects into left- and right-handers. However as Chapter One has outlined, this is far from ideal.

6.3 PROBLEMS WITH CURRENT HANDEDNESS RESEARCH

The validity of the results from the present study and that of Halpern and Coren (1988) rest on the assumption that valid indices of handedness have been employed. Unfortunately, as pointed out in Chapter One, the traditional strategy of dichotomising people into left- and right-handers may be inappropriate because handedness is apparently multi-dimensional. While some people are solely left- or right-handed for tasks, there are many who show aspects of mixed handedness. These people may be left-handed for one dimension of handedness (e.g., strength) and right-handed for others (e.g., accuracy). If handedness is multi-dimensional then dichotomisation is unwarranted since it places subjects who may have quite disparate characteristics together, thereby obscuring differences within and between handedness groups.

Related to the problem of the dichotomisation of handedness is the arbitrariness of handedness definitions. These both stem from the fact that nobody is certain exactly what left-handedness is. This means that different researchers use different definitions of handedness and these are often arbitrary with no real justification for the method of classification. Arbitrary points along questionnaire scoring guides are then used to categorise subjects into left- and right-handers. Although it is sometimes acknowledged that there are mixed-handers this distinction is not subtle enough to detect such groups as inconsistent left-handers (those who write left-handed but throw right-handed).

It is only when meaningful answers have been found to the question of 'what is handedness?' that useful comparisons can be made between groups with different handedness characteristics. Before this though, sound theoretical reasons need to be provided before comparisons are made. Why should a person's handedness affect their immune system or maturational pattern?

6.4 DIRECTIONS FOR FUTURE RESEARCH

The bulk of handedness research has been based on a format of selecting left- and right-handers using short questionnaires and comparing these groups on a chosen variable to see if there is a difference. Despite criticism going back many years (e.g., Palmer, 1964, 1974; Barnsley & Rabinovitch, 1970) and results in the literature that are contradictory and equivocal, this practise has continued. It is time to approach handedness research in a different way in an endeavour to provide some meaningful answers to the puzzles posed by the existence of left-handers.

Rather than persevering with studies comparing left- and right-handers where the outcomes are often conflicting and confusing, research should concentrate on determining what handedness is. This may be accomplished by determining the factors that make a person more proficient with one hand than the other. It may involve concentrating on the physiology of hand movement and using performance measures as a means of assessment The work on force modulation (Peters, 1980) is important in this respect and provides a platform for future research.

Another way of examining handedness could be to construct an in-depth case study of an individual's handedness using a variety of performance and preference measures such as finger tapping (Peters & Durding, 1979) and peg moving (Annett, 1970). Subjects could also be interviewed to ascertain what aspects they believe differentiate between their two hands (i.e., is it a lack of control in the non-preferred hand as Peters and Durding, 1979 suggest?). If this type of case study is conducted on a number of people, it is possible that patterns of similarities and differences may begin to emerge. Perhaps some left-handers with certain attributes are more likely to have immune disorders, dyslexia or other disorders that are often thought to be related to left-handedness despite contradictory evidence.

This type of in-depth analysis could be conducted within the context of longitudinal studies. A major problem is that many studies on left-handedness, particularly those concerning age are cross-sectional. This makes it difficult to determine if any age related changes found are due to differences in the cohorts being studied, or whether changes in handedness do occur with age. A longitudinal study would also be able to examine skill acquisition and the pressures, if any, that children may come under to change hands. The effect of practice could also be determined. For instance if a child has been taught to use the non-preferred hand for a task, will they continue to use this hand for a task that is different but has many of the same properties as the first task?

Perhaps it is also time for left-handedness to be studied in its own right rather than as an indirect and dubious marker for those who may have bilateral or right hemispheric speech lateralization. A sizeable minority of people have left-handed tendencies and while there is much anecdotal evidence (e.g., Paul, 1990) about the problems of being left-handed in a right-handed world, this is still an area where research is needed. It is also an area that is becoming even more important as the numbers of left-handers in the population appear to be increasing.

The beliefs and knowledge that left-handers and their families have about left-handers is another possible area of research. It is known that many left-handed individuals are interested in their handedness and left-handers are more aware of others' handedness than are right-handers (Etaugh & Brausam, 1978). Much has been published in the popular press about the supposed abilities and deficits of left-handers and it would be interesting to know what attributes left-handers feel they have and what affect, if any, this has on their capabilities.

6.5 LATERALITY AND MYTH

Corballis (1980) has outlined the ways in which left and right have been associated with different characteristics since ancient times. Almost without exception the left has been associated with negative or evil, and the right with all that is positive and good. He suggests that Psychology has been influenced by a myth of laterality as evidenced by the way in which the duality of the brain and the differences rather than the similarities of the hemispheres have been emphasised.

Psychology too, has continued the tradition of labelling the left as defective and the right as good. As Chapter Two has pointed out, there are conflicting and equivocal results from the studies that have examined the relationship between handedness and a variety of disorders such as dyslexia. However the conflicting evidence is often ignored, as was done by Coren and Halpern (1991) and relationships between left-handedness and disorders treated as fact. In this way the myth of laterality is perpetuated with equivocal findings being reported as the truth. If these findings are then used as the basis for a theory (e.g., Geschwind & Galaburda, 1987) then a relationship such as the one between left-handedness and allergies can become entrenched in popular thinking when the evidence is far from strong. The argument against the myth of laterality is not arguing against the possibility of left-handers being deficient in some areas when compared to right-handers. This may be the case. It is arguing against deficits and disorders being linked with left-handedness when there is no compelling evidence for this.

Psychology, using appropriate research methods, should be able to help distinguish between the myth and the reality of left-handedness but this does not appear to have been the case. Rather, psychological research has contributed to the myth of laterality by continuing to dichotomise subjects into two handedness groups and by producing conflicting and equivocal results in this area. The increasing evidence for sub-groups and the multi-dimensional nature of handedness make it apparent that there is little use in continuing this dichotomisation. The sooner this realization is made by those in handedness research, the sooner Psychology will stop contributing to the myth of laterality and begin to provide some useful and informative answers to the questions 'what is left-handedness?' and 'what is its genesis?'

6.6 CONCLUSION

The aim of this thesis was to investigate the claim of Coren and Halpern (1991) that left-handers are more likely to die at a younger age than right-handers. As has been shown, the two studies that Coren and Halpern (1991) claim support this conclusion are seriously flawed either in the way the data was collected, or in the way it was analysed, and other supporting evidence for their claim is not as strong as it appears. There is also no reason to suggest, as

Coren and Halpern (1991) do, that the influence of cultural pressure is not sufficient to explain the dearth of left-handers found in older age groups. While it cannot be entirely ruled out that some left-handers, especially those referred to as pathological, may have a lower life expectancy than the rest of the population, Coren and Halpern (1991) have not convincingly shown that left-handers overall are likely to die at a younger age. The conclusion of this thesis is that it is yet to be proven that left-handedness is a marker for decreased survival fitness.

It may be tempting to conduct additional research to address this issue further, especially the interesting suggestion that left-handers may have died younger in the past, but now do not. However reasearch would be better spent focusing on what it is that makes one hand the preferred one and the ways in which handedness may be multi-dimensional.

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APPENDIX A

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